



Digitized by the Internet Archive
in 2018 with funding from
University of Illinois Urbana-Champaign

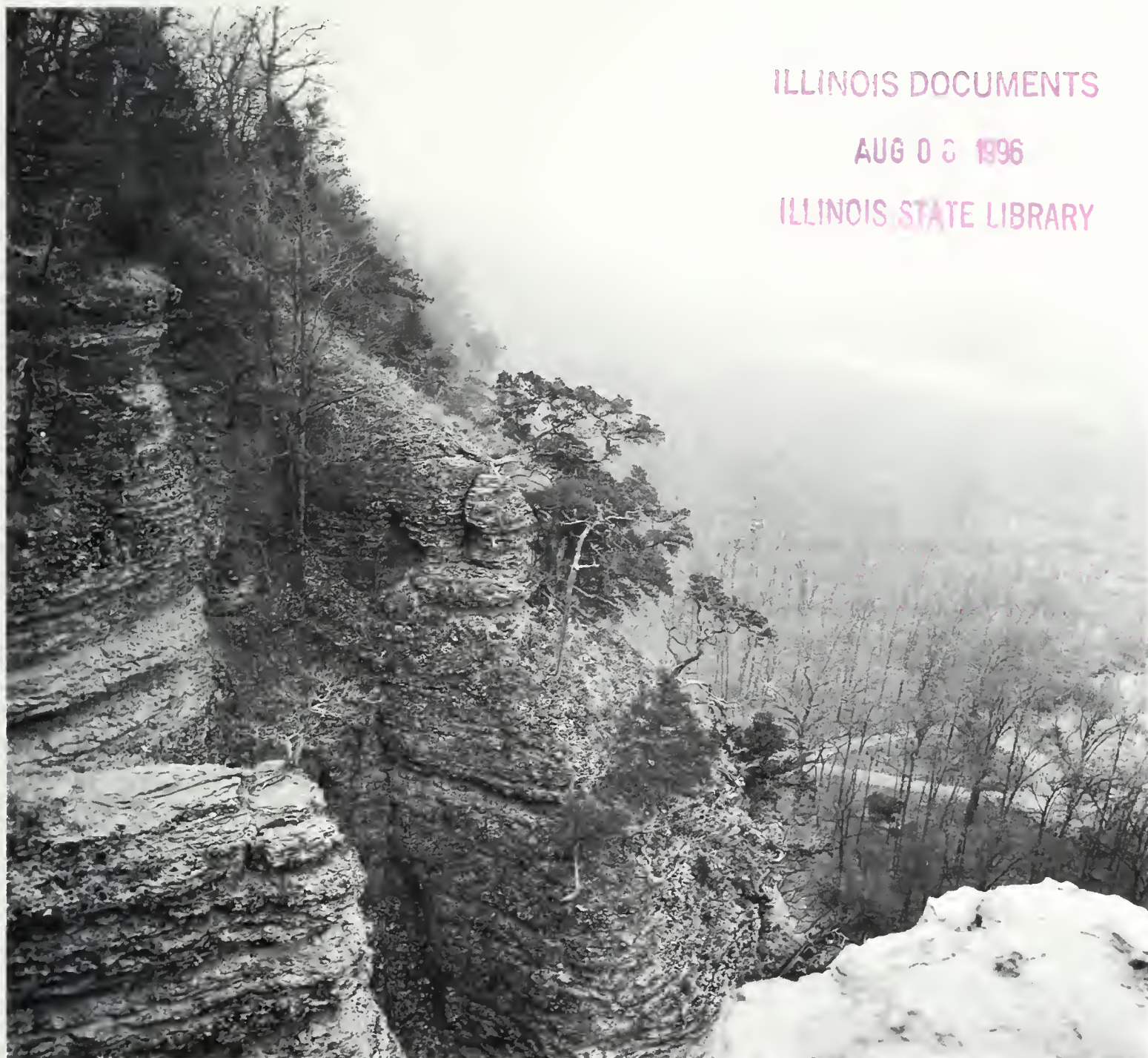
<https://archive.org/details/bedrockgeologyof00nels>

35173762

1557
Gb-102
c.3

BEDROCK GEOLOGY OF THE PADUCAH 1° × 2° QUADRANGLE Illinois, Kentucky, and Missouri

W. John Nelson



ILLINOIS DOCUMENTS

AUG 06 1996

ILLINOIS STATE LIBRARY

Bulletin 102 1995

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

e. 3

BEDROCK GEOLOGY OF THE PADUCAH 1° × 2° QUADRANGLE Illinois, Kentucky, and Missouri

W. John Nelson

Bulletin 102 1995

ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820-6964



Cover photo The view is southwest from the crest of Pine Hills across La Rue Swamp on the Mississippi River floodplain, northwestern Union County. The bluffs are composed of the Grassy Knob Chert overlying the Bailey Limestone (both Lower Devonian). Photo by Joel Dexter.

ACKNOWLEDGMENTS

The map and report for this project were prepared as part of the Conterminous United States Mineral Assessment Program (CUSMAP), a cooperative program involving the U.S. Geological Survey and various state geological surveys. Many individuals participated in CUSMAP and helped prepare the bedrock geologic map and report. The following people reviewed the map and report, and contributed valuable source materials: Dewey H. Amos, James W. Baxter, Garland Dever, Anne Graese, Mark A. Middendorf, Martin C. Noger, Wilds W. Olive, Charles E. Robertson, Thomas L. Thompson, and John W. Whitfield.



Printed by authority of the State of Illinois/1995/1200



printed with soybean ink on recycled paper



CONTENTS

ABSTRACT	1
INTRODUCTION	2
STRATIGRAPHY	3
Precambrian and Cambrian Rocks	3
Ordovician System	5
Canadian Series: Knox Group	5
Champlainian Series	6
Cincinnatian Series	8
Silurian System	9
Alexandrian Series	10
Niagaran and Cayugan (?) Series: Bainbridge Formation	10
Silurian (?) and Devonian Systems	10
Tamms Group	10
Middle Devonian Series: Muscatatuck Group	11
Mississippian System	13
Kinderhookian Series	13
Valmeyeran Series	13
Chesterian Series: Pope Group	18
Pennsylvanian System	24
Cretaceous System	26
Tertiary System	27
Paleocene Series: Midway Group	27
Eocene Series	27
STRUCTURAL GEOLOGY	28
Regional Setting	28
Tectonic History	28
Individual Structures	30
REFERENCES	34
ADDENDUM TO PLATES	40

TABLE

1 Changes in formal stratigraphic nomenclature introduced in this report	3
--	---

FIGURES

1 Generalized stratigraphic column	4
2 Relationships of lower and middle Mississippian rocks in study area	14
3 Differences in Mississippian stratigraphic nomenclature between Illinois and Kentucky	16
4 Facies and nomenclature changes in lower part of Pope Group	19
5 Carbondale Formation as defined in this report	25
6 Major structural features of the Paducah 1° × 2° Quadrangle	29

PLATES

1 Paducah 1° × 2° quadrangle geologic map
2 Bedrock geology of the Carbondale 30 × 60-minute quadrangle
3 Bedrock geology of the West Frankfort 30 × 60-minute quadrangle
4 Bedrock geology of the Cape Girardeau 30 × 60-minute quadrangle
5 Bedrock geology of the Paducah 30 × 60-minute quadrangle



ABSTRACT

The Paducah 1° × 2° Quadrangle, bounded by latitudes 37° and 38° N and longitudes 88° and 90° W, covers portions of southern Illinois, southeastern Missouri, western Kentucky, and the southwestern corner of Indiana. Parts of three major geologic provinces, the Ozark Dome, Illinois Basin, and Mississippi Embayment, are within the Paducah Quadrangle. The area features complex structure, including numerous fault zones reactivated repeatedly from Cambrian through Tertiary time.

Sedimentary rocks of Lower Ordovician through Middle Devonian age crop out on the east flank of the Ozark Dome, in the western part of the Paducah Quadrangle. The rocks are largely limestone and dolomite; major siliciclastic intervals are the St. Peter Sandstone (Middle Ordovician) and the Maquoketa Group (Upper Ordovician). These strata dip regionally eastward toward

the Illinois Basin and are intricately faulted; the prevalent fault trends are northwest and northeast. The Ste. Genevieve Fault Zone, which borders the north flank of the dome, underwent normal faulting during the Devonian Period and reverse faulting in late Mississippian to early Pennsylvanian time.

The northern, central, and eastern parts of the study area are within the Illinois Basin, where sedimentary rocks of Devonian through Pennsylvanian age are at the surface. The deepest areas of the basin are north and east of the Paducah Quadrangle. Faulting in the southeastern part of the quadrangle is the surface expression of a Cambrian failed rift that was precursor to the present Illinois Basin. Faults of the Rough Creek-Shawneetown and Pennyrile Fault Systems and Fluorspar Area Fault Complex have undergone several episodes of normal, reverse, and

oblique-slip displacements in response to changing stress regimes. Other important structures in the Illinois Basin area are the Wabash Valley and Rend Lake Fault Systems (normal faulting) and Cottage Grove Fault System (right-lateral wrench faulting).

Weakly lithified Cretaceous and Tertiary sediments overlap Paleozoic Mississippian Embayment, in the south-central Paducah Quadrangle. Structure of the Embayment is poorly known due to widespread cover by Quaternary sediments and sparse borehole information. Along the northern margin of the Embayment, reactivated northeast-trending faults displace strata as young as Pliocene. Tectonic activity continues today in the New Madrid seismic zone, immediately south of the Paducah Quadrangle.



INTRODUCTION

This report accompanies the bedrock geologic map of the Paducah 1° x 2° Quadrangle. The map and report were prepared under the Conterminous United States Mineral Assessment Program (CUSMAP), a joint project of the U.S. Geological Survey and various state geological surveys. The bedrock map (plate 1) is part of a complete folio of maps being prepared under CUSMAP. The map is accompanied by separate sheets that show columns and structural cross sections (plates 2–5).

The bedrock map was compiled from published and unpublished maps and reports. No new surface mapping was conducted, although well records were used to aid in placing contacts beneath Quaternary deposits of the Mississippi and Ohio River floodplains. Well logs were also used to construct stratigraphic columns and cross sections. Well records are on public file at the Illinois, Kentucky, and Missouri Geological Surveys. Sources of information are shown on inset maps and listed in the references of this report.

This map shows bedrock geology only. Quaternary deposits, including the Pliocene (?)–Pleistocene sediments commonly called “Lafayette” or Mounds Gravel, were omitted. Surficial geology (to a depth of 15 meters) is mapped and described elsewhere in the CUSMAP folio. Where surficial deposits are thick and extensive, particularly on the Mississippi and Ohio River floodplains, bedrock contacts and faults were projected from outcrops and inferred from well data. Borehole

data are sparse; hence, concealed contacts and faults are highly inferential.

Other compilation maps and reports that cover portions of the Paducah Quadrangle include the bedrock geologic maps of Illinois (Willman et al. 1967), Kentucky (McDowell et al. 1981), and Missouri (Anderson 1979). A text by McDowell et al. (1986) describes the geology of Kentucky. A geologic map and report on the stratigraphy and structure of the western Kentucky fluorspar district were prepared by Trace and Amos (1984). Geology of the Jackson Purchase region (Mississippi Embayment in western Kentucky) was mapped and described by Olive (1980). Structural features of Missouri were compiled by McCracken (1970) and those of Illinois by Treworgy (1981) and Nelson (1995). All of these sources were consulted in preparing the Paducah bedrock map. The geology of the Kentucky portion of the map was taken mainly from McDowell et al. (1981) and modified with reference to the 7.5-minute geologic quadrangle maps.

Data on the map that accompanies this report were compiled at a scale of 1:100,000, and are meant to be used at that scale or smaller. Geology was generalized and simplified in some areas to maintain legibility. Also, unavoidable errors (hopefully minor) were introduced in reducing, tracing, and digitizing original source maps. Users who wish to study bedrock geology of the Paducah Quadrangle at scales larger

than 1:100,000, should consult the original source materials cited herein.

This report is basically a descriptive account of stratigraphy and structural geology of the Paducah Quadrangle. The many geologists who have mapped in the Paducah Quadrangle differ in their approaches to stratigraphy and structure. To avoid “state-line faults,” the compiler must assess and judge the validity of adjacent maps. Accordingly, much space is devoted to explaining the basis for my judgments, particularly on stratigraphic nomenclature. I have recommended new classification and resolved some stratigraphic problems, where possible; yet, many issues require further study. A more interpretive account of the depositional and tectonic history of the Paducah Quadrangle is in preparation for publication by the U.S. Geological Survey.

The description of rock units and structural features contained herein was abstracted from a wide variety of published and unpublished sources. These sources have been supplemented greatly by my own observations during mapping in southern Illinois and less extensive field studies in Missouri and Kentucky. Inconsistencies in descriptions (e.g., carbonate classifications) remain, because personal inspection of geology throughout the Paducah Quadrangle was impossible. Incomplete and contradictory descriptions of geologic units and features point out the need for continued study.



STRATIGRAPHY

This work is a compilation of mapping conducted for more than 70 years by geologists who worked for many different institutions. Consequently, the names, ranks, and definitions of lithostratigraphic units differ from one source map to the next. As compiler, I attempted to standardize stratigraphic classification (fig. 1) throughout the Paducah Quadrangle, and to bring nomenclature into conformity with the North American Stratigraphic Code (1983). In particular, I applied Article 24 of the Code, which recognizes the formation as the fundamental lithostratigraphic unit and mandates that a valid formation be mappable "at the scale of geologic mapping practiced in the region when (sic) the formation is proposed." In accordance with this Article, I reduced the ranks of some units previously called formations that do not meet the test of mappability (table 1). Other stratigraphic problems involving units, the names or definitions of which change at state boundaries, are noted but not resolved. Resolving these problems will require more comprehensive study beyond the scope of this report.

The descriptions of stratigraphic units that follow were mainly abstracted from the geologic maps and accompanying texts. Constraints of the study did not permit inspection of outcropping strata, or even a comprehensive literature search for all stratigraphic data relevant to the Paducah Quadrangle. Thus, the level of detail and the terminology used in the descriptions may vary. An effort was made to standardize descriptions of units as much as possible, by referring to published sources.

PRECAMBRIAN AND CAMBRIAN ROCKS

Precambrian and Cambrian rocks underlie the entire area covered by the Paducah Quadrangle, but they do not crop out. Because this set of

Table 1 Changes in formal stratigraphic nomenclature introduced in this report.*

Age	Previous usage	This report
Cambrian-Ordovician	Knox Megagroup (Swann and Willman 1961)	Knox Group
Silurian (?) - Devonian	Tamms group (Rogers 1972)	Tamms group, published for the first time
Devonian	Muscatatuck Group (Shaver 1974 for Indiana only)	Muscatatuck Group, usage extended to study area
Devonian-Mississippian	New Albany Group (Swann and Willman 1961)	New Albany Shale (formation)
Mississippian	Mammoth Cave Megagroup (Swann and Willman 1961)	Mammoth Cave Group, lower boundary redefined
Mississippian	Chester Group (Worthen 1866) Chester Series (S. Weller 1920) Pope Megagroup (Swann and Willman 1961)	Pope Group
Mississippian	Cedar Bluff Group (Swann 1963)	Cedar Bluff Limestone (formation)
Mississippian	West Baden Group (Gray et al. 1960)	West Baden Sandstone (formation)
Mississippian	Paint Creek Group (Swann 1963)	Paint Creek Formation
Mississippian	Golconda Group, contains Haney Limestone, Fraileys Shale, and Beech Creek Limestone Formations (McFarlan et al. 1955; Swann 1963)	Golconda Formation, contains Haney, Fraileys, and Beech Creek Members
Mississippian	Okaw Group (Swann 1963)	Okaw Limestone or Formation
Pennsylvanian	McLeansboro Formation (DeWolf 1910) McLeansboro Group (Kosanke et al. 1960) Sturgis Formation (Kehn 1973)	McLeansboro Group (Sturgis suppressed)

*Many of the above changes represent reversion to older usage, or reflect usage previously accepted by some geologists in some areas. Rationale for changes is explained in the text.

maps and report is concerned with outcropping bedrock, Precambrian and Cambrian rocks are not described herein (although they are indicated on some of the cross sections

that accompany the bedrock map). Those interested in Precambrian and Cambrian geology should refer to maps that appear elsewhere in the CUSMAP folio.

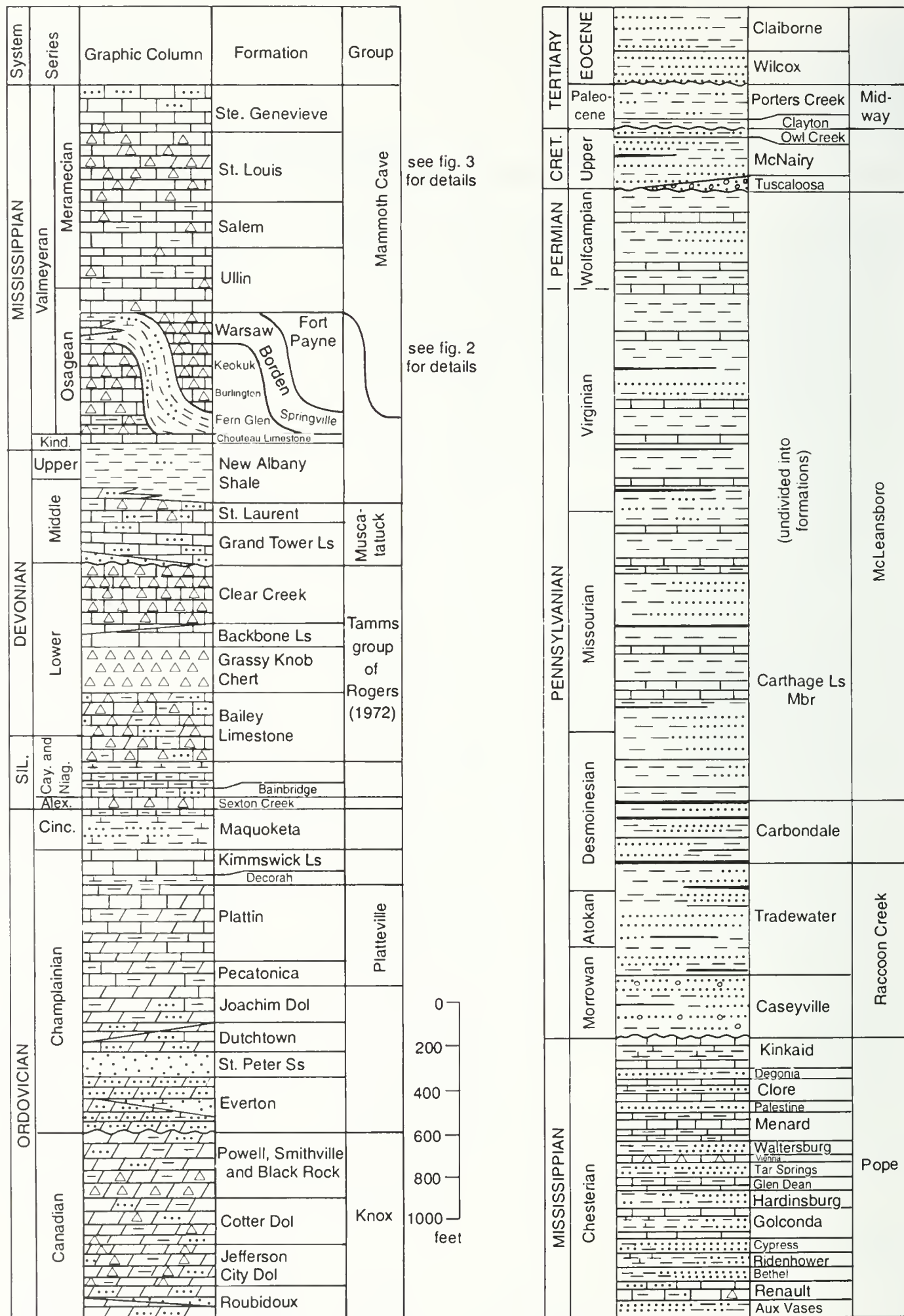


Figure 1 Generalized stratigraphic column of rocks exposed in the Paducah 1° x 2° Quadrangle.

ORDOVICIAN SYSTEM

Canadian Series: Knox Group

The name Knox is widely applied to the thick succession of St. Croixan (Upper Cambrian) and Canadian carbonate rocks (dominantly dolomite) in the subsurface of the southern Illinois Basin. The Knox Group was originally defined in outcrops near Knoxville, Tennessee (Safford 1869), and later traced through the subsurface into western Kentucky. Equivalent rocks that crop out on the Ozark Dome in Missouri are assigned to various formations but not combined into groups. The Ozark formations are difficult to identify in subsurface because of apparent downdip changes in facies and a lack of distinguishable lithologic criteria in well logs and samples.

The Knox is classified as a formation (Knox Dolomite) or group across a large area of the eastern United States. Swann and Willman (1961) classified the Knox as a megagroup in Illinois; their usage was followed in publications of the Illinois State Geological Survey. Droste and Patton (1985), noting that the North American Stratigraphic Code (1983) does not recognize megagroups, designated the Knox as a supergroup in Indiana. The Code (1983, p. 859) defines a supergroup as "a formal assemblage of related or superposed groups, or of groups and formations." The only group that has been recognized within the Knox is the Prairie du Chien Group, the type area of which is in southwestern Wisconsin. The Prairie du Chien and its constituent formations have been described in northern Indiana and Illinois, but they apparently are not traceable into the area of the Paducah Quadrangle. No control wells in southwestern Indiana were available to Droste and Patton (1985). In Illinois, Willman et al. (1975, p. 51) stated, "South of (a line between Edgar and Monroe Counties, north of the Paducah Quadrangle) the base of the Prairie du Chien cannot be picked with confidence...."

Even if the boundaries of the Prairie du Chien Group could be traced into southern Illinois, usage of the name Prairie du Chien Group in this area would be inadvisable. Groups are customarily named to distinguish assemblages of similar formations from adjacent units of

contrasting lithology. The Prairie du Chien in Wisconsin is a logical group; it comprises carbonate formations between the St. Peter Sandstone above and the Jordan Sandstone below. The Jordan Sandstone grades southward into dolomite of the Eminence Formation in northern Illinois (Buschbach 1964). Thus, the Prairie du Chien loses its identity as a group and becomes merely the upper part of a thick succession of carbonate rocks that are properly combined as a single group, the Knox.

Thus, the Knox is reclassified as Knox Group in this report, replacing Knox Megagroup or Supergroup. The Prairie du Chien Group should be restricted to areas where the Jordan Sandstone or equivalent clastic units are present.

Canadian strata that crop out in southeastern Missouri are predominantly dolomite interbedded with minor amounts of limestone, chert, shale, and sandstone. Named formations are similar to one another in lithology and commonly have gradational or intertonguing contacts. Different geologists mapping in the region applied different criteria for defining units; therefore, in some places contacts do not match at the borders of adjacent quadrangles. The most serious mismatches of contacts occur at the borders of the Perryville West Quadrangle (Middendorf and Whitfield 1991b) with the Lithium (Amos 1986c) and Sedgewickville (Amos 1984) Quadrangles. Resolving these discrepancies would require extensive field study and remapping of the contacts, which were beyond the scope of this study. I have depicted all contacts as shown by their respective authors. Mismatched contacts are connected by dotted lines that follow quadrangle boundaries.

Roubidoux Formation The oldest bedrock unit exposed in the Paducah Quadrangle is the Roubidoux Formation of early Canadian age. The Roubidoux crops out along the west edge of the quadrangle in Missouri (plate 1). The Roubidoux in this area is composed of dolomite and sandstone; dolomite constitutes approximately two-thirds of the formation. The dolomite is light to medium gray and light brown, and microcrystalline to finely crystalline;

locally, it is medium crystalline. The dolomite is commonly sandy and contains numerous chert layers and lenses up to about 1 foot thick. Bedding is mostly medium to thick, but some thin beds are present. Sandstone in the Roubidoux is light gray to yellowish brown, fine to medium grained, and composed almost entirely of quartz grains, some of which are frosted. Most of the sandstone is medium to thick bedded, but some is thin bedded and displays ripple marks.

The maximum exposed thickness of the Roubidoux in the study area is 160 feet. Wells near the outcrop belt indicate a total thickness of 155 to 320 feet; thickness generally increases southward. Eastward in the subsurface, the sandstone beds pinch out and the Roubidoux becomes indistinguishable from adjacent formations.

Jefferson City Dolomite The Jefferson City Dolomite crops out in an irregular, faulted belt along the west edge of the map area (plate 1). This unit is composed of cherty dolomite and occasional interbeds of shale and sandstone. Dolomite is light to medium gray and yellowish brown, microcrystalline to finely crystalline, and thin to medium bedded. It is typically argillaceous, and some beds are silty to sandy, particularly in the upper part of the formation. Beds of massive, pitted dolomite occur at various positions throughout the Jefferson City and the overlying Cotter Dolomite (M.A. Middendorf, Missouri Division of Geology and Land Survey, written communication, 1989). One such bed that occurs 30 to 60 feet above the base of the Jefferson City is informally called the quarry ledge. Interbeds of gray to greenish gray dolomitic shale are found mainly in the lower two-thirds of the Jefferson City. Beds of light gray, fine grained quartzose sandstone are also present.

Much mapping of Canadian rocks in southeastern Missouri is based on the character of residual soils. The Jefferson City yields a distinctive residuum of red to yellow plastic clay that contains abundant fragments of porous, partly oolitic chert.

Thickness of the Jefferson City in the outcrop belt in the Paducah 1° × 2° Quadrangle ranges from 165

to 280 feet, and generally increases southward. In the subsurface of Illinois and western Kentucky, the Jefferson City Dolomite cannot be separated from other dolomites of similar lithology in the Knox Group. The contact to the Roubidoux is "probably unconformable" (M.A. Middendorf, Missouri Division of Geology and Land Survey, written communication, 1989).

Cotter Dolomite The Cotter Dolomite was mapped in a faulted belt that lies east of Jefferson City outcrops near the western border of the study area in Missouri (plate 1). Like the Jefferson City, the Cotter is a unit of cherty dolomite that contains thin shale and sandstone interbeds. The dolomite is light grayish brown, microcrystalline to medium crystalline, and largely medium to thick bedded. Some beds are silty to sandy. Chert bands as thick as 2½ feet occur throughout the Cotter, but they are most numerous in the middle and upper portions. Distinctive features of the Cotter include stromatolitic or algal masses, drusy quartz, and edgewise conglomerate. Oolitic dolomite and chert are present in places. Beds of fine grained, quartzose sandstone in the Cotter range from a few inches to 2 feet thick. A fairly persistent sandstone bed about 60 feet above the base of the formation is informally called the Swan Creek sandstone.

The Cotter Dolomite in the outcrop belt thickens from about 90 feet north to 380 feet south. The contact to the Jefferson City Dolomite is disconformable in some places, and conformable and gradational in others. The Cotter has not been mapped in the subsurface east of the outcrop belt.

Powell, Smithville, and Black Rock Formations The Powell Dolomite and Smithville and Black Rock Formations are recognized in southeastern Missouri by some geologists but not by others. All three formations were originally defined in northern Arkansas. On available source maps for Missouri, the Powell, Smithville and Black Rock are generally mapped as a single unit, or informally divided into lower, middle, and upper units. A diagrammatic cross section for the White-water Quadrangle (Amos 1981b)

shows the Powell Dolomite at the base, overlain by and intertonguing with the Smithville Formation, which in turn is overlain by and intertongues with the Black Rock Formation. In the Perryville West Quadrangle, Middendorf and Whitfield (1991b) assigned to the Cotter Dolomite strata that are mapped as Powell and Smithville in surrounding quadrangles (plate 1). This interval of rocks clearly requires further study. On plate 1, the Powell, Smithville, and Black Rock Formations are depicted as the undivided, single unit they are shown as on source maps. Mismatched contacts are indicated by dotted lines along quadrangle borders.

Undivided Powell, Smithville, and Black Rock strata were mapped in large areas of the westernmost two tiers of 7.5-minute quadrangles in the study area (plate 1). The interval consists chiefly of light brownish gray, microcrystalline to finely crystalline dolomite. This rock is largely thick bedded to massive, but intervals of thin bedded shaley dolomite are present. The lower part of the interval tends to be less shaley and contains abundant chert nodules up to 6 inches in diameter and beds of chert as thick as 3 feet. Gastropods, trilobites, cephalopods, ostracods, bryozoans, brachiopods, rostroconchs, stromatolites, and algal structures are present in the lower part of the interval. The upper part of the interval is less fossiliferous and contains less chert. Interbeds of light greenish gray shale and very fine to fine grained, silty, dolomitic sandstone occur in the middle and upper part of the interval.

The undivided Powell, Smithville, and Black Rock Formations thicken southward from about 170 to 600 feet. The contact to the Cotter Dolomite is reported to be sharp but conformable (Amos 1981a, 1987a). The Cotter-Powell contact was described as unconformable in Ste. Genevieve County, Missouri, immediately west of the Paducah Quadrangle (S. Weller and St. Clair 1928).

Champlainian Series

Everton Formation The main outcrop belt of the Everton Formation extends south-southeast from northwestern Perry County to northwestern Scott County (plate 1). This outcrop belt is offset by numerous

faults. The Everton is also mapped in small fault slices within the Ste. Genevieve Fault Zone in northern Perry County.

The Everton is a unit of interbedded sandy dolomite and sandstone. Dolomite, which constitutes two-thirds to three-fourths of the formation, is typically light to medium gray, fine grained, and medium to thick bedded. Floating grains of well rounded, frosted quartz sand are common. Fossils generally are poorly preserved, but algal structures are common. The dolomite is slightly to moderately cherty. Sandstone in the Everton is white to light gray, fine grained quartz arenite composed of frosted and well rounded sand and dolomitic cement. The Everton also contains intermittent thin beds of gray to greenish gray shale, and a small amount of limestone near the top.

Like the underlying formations previously described, the Everton thickens toward the south and south-east. On the outcrop, it thickens from about 70 feet in northern Perry County to 380 feet in southern Cape Girardeau County. It is more than 400 feet thick in the subsurface in southernmost Illinois (Collinson et al. 1988). The lower contact of the Everton is disconformable throughout the outcrop belt, but it may become conformable in the subsurface where the Everton is thickest (Collinson et al. 1988).

St. Peter Sandstone The St. Peter Sandstone crops out in a narrow belt east of the Everton cropline in Perry and Cape Girardeau Counties, Missouri, and also occurs in slices within the Ste. Genevieve Fault Zone (plate 1). The St. Peter is a distinctive unit that consists of nearly 100% quartz sand. The sand is white to light brown, fine to medium grained, well sorted, well rounded, and frosted. Generally the rock is friable and case-hardened, but near faults, it is commonly silicified and contains white quartz veinlets. The sandstone is thick bedded to massive and, in places, it displays crossbedding and ripple marks.

The St. Peter is as much as 210 feet thick; locally it is absent. No thickness trends are evident in the outcrop belt. In the subsurface, the St. Peter thins eastward and south-eastward to less than 50 feet (Collin-

son et al. 1988). The lower contact is disconformable according to most geologists; however, Johnson (1985a) reported the contact to be conformable in the Scott City and Thebes Quadrangles.

Dutchtown Formation Because the Dutchtown Formation is relatively thin, it was combined with the overlying Joachim Dolomite on the geologic map (plate 1). The Dutchtown crops out immediately east of the St. Peter, along a faulted strip that runs south-southeast through Perry and Cape Girardeau Counties, Missouri.

The Dutchtown is a unit of medium to very dark gray and brownish gray carbonate rock that is very fine to fine grained and silty to sandy. Most of the carbonate rock is dolomite; however, limestone becomes an important constituent of the Dutchtown toward the south. It contains bitumen-filled vugs and gives a petroliferous odor when struck. Fossils include pelecypods, gastropods, brachiopods, ostracods, and conodonts. Cryptozoan reefs occur near the middle of the Dutchtown in the Thebes and Scott City Quadrangles. Thin beds of brown, fine grained dolomitic sandstone and greenish gray shale occur in the formation.

The Dutchtown thins northward from 185 feet in southern Cape Girardeau County to 20 feet or less in northern Cape Girardeau and Perry Counties. The contact of the Dutchtown to the St. Peter is disconformable according to quadrangle mappers in Missouri; however, Templeton and Willman (1963) stated that the Dutchtown-St. Peter contact appears to be gradational north of Cape Girardeau.

Joachim Dolomite The Joachim Dolomite was combined with the underlying Dutchtown on the geologic map (plate 1); the outcrop trends south-southeast through Perry and Cape Girardeau Counties, interrupted by numerous faults.

Lithologically the Joachim is dominantly dolomite, but it contains a lesser amount of limestone and minor interbeds of shale and sandstone. Dolomite is light to medium gray and brown, very fine to fine grained, and partly sandy. Bedding varies from thin to thick. Limestone,

which occurs mainly in the upper part of the Joachim, is micritic to "finely crystalline" and medium to thick bedded. Mud cracks that have downturned edges, raindrop impressions, rill marks, ripple marks, and disseminated gypsum and anhydrite occur in the Joachim (Templeton and Willman 1963, p. 58). Chert is sparse in the upper part of the Joachim and generally absent in the lower part. Yellowish brown, fine grained sandstone occurs in beds as thick as 6 feet mainly in the lower part of the Joachim toward the south. Thin interbeds of gray dolomitic shale are scattered throughout the formation.

On the outcrop, the Joachim thickens southeastward from about 130 to 275 feet. Southeastward thickening of the combined Joachim and Dutchtown is also evident in the subsurface in Illinois. The two formations reach a combined thickness of more than 600 feet at the southeastern corner of Illinois (Willman et al. 1975, p. 63). The nature of the lower contact is controversial. Thompson (1991, p. 87) declared it to be conformable, but Martin et al. (1961) and most authors of geologic quadrangle maps reported the contact to be disconformable. Templeton and Willman (1963, p. 54) reported the contact to be gradational and intertonguing in most places, except near Cape Girardeau, where evidence of a minor diastem is present.

Pecatonica Formation The interval of limestone and dolomite between the Joachim and Plattin Formations is called the Pecatonica Formation by several of the geologists who mapped in the Missouri portion of the Paducah Quadrangle. The Pecatonica was originally described in southern Wisconsin, and it is a distinctive formation in northern Illinois (Templeton and Willman 1963). In southeastern Missouri, however, the Pecatonica is nearly identical in lithology to the Plattin Formation, and probably was not mapped consistently from one 7.5-minute quadrangle to another. Thompson (1991, p. 109) states that the Pecatonica can be identified with certainty at only a few sites in Missouri, and he regards the future use of this name in Missouri as "tentative and questionable." Accordingly, the Pecatonica and Plattin Forma-

tions (along with the thin Decorah Formation) are combined into a single unit on the map that accompanies this report (plate 1).

The outcrop belt of the undivided Decorah, Plattin, and Pecatonica is broad in Perry County, and narrows southward in Cape Girardeau and Scott Counties. The southward narrowing of the outcrop mainly reflects increased dip of the strata on the south.

The Pecatonica consists of intercalated dolomite and limestone and thin shale interbeds. Carbonate rocks are light to medium brownish gray and micritic to finely granular or crystalline. Bedding is mostly medium to very thick. Some of the limestone gives off a petroliferous odor when struck. Fossils include brachiopods, ostracods, and algae. Portions of the Pecatonica are burrowed ("fucoidal"), and in the lower part, beds of brown laminated dolomite and dark gray laminated limestone alternate (Thompson 1991). The upper part of the formation contains chert. Medium gray shale occurs as partings and thin interbeds throughout the formation.

The Pecatonica is reported by quadrangle mappers to be 80 to 150 feet thick in most of the study area. Amos (1985c) indicated a maximum thickness of 290 feet in the Altenburg Quadrangle, southeastern Perry County. According to Thompson (1991), the Pecatonica is absent north of Perry County and reaches a maximum of 140 feet in Cape Girardeau and Scott Counties. Amos and Thompson evidently have different perceptions of the Pecatonica Formation. The need for further study of this interval is clear.

Plattin Formation For reasons outlined in the preceding section, the Plattin Formation is combined with the underlying Pecatonica Formation on the geologic map (plate 1). The thin Decorah Formation, which overlies the Plattin, was combined in the same map unit because it was combined with the Plattin on many of the source maps. The Plattin was classified as a formation, or a group divided into several formations (Thompson 1991). None of the quadrangle mappers in the study area subdivided the Plattin.

The Plattin is lithologically similar to the Pecatonica. Most quadrangle

gle mappers did not clearly explain how they differentiated the two units. The Plattin is composed largely of light to medium gray and brownish gray, "sublithographic" (micritic) limestone and dolomite in thin to thick beds. Wavy bedding and "fucoidal structures" (burrows) are reported to be characteristic for the Plattin. Thompson (1991) described the burrows as ranging from ¼ to 2 inches in diameter and commonly filled with brown to tan dolomite. The burrow fillings weather out, producing a distinctive pitted or honeycombed surface on the outcrop. The Plattin also contains pelletal carbonates, intraformational conglomerates, and diverse fossils, including brachiopods, gastropods, cephalopods, pelecypods, ostracods, corals, and bryozoans. Nodules of light colored, dense chert are present. Shale occurs as partings or thin beds and is gray to greenish gray. A thin unit of oolitic limestone, the Brickkeys Member, occurs near the base of the Plattin. The thin but widespread Establishment Shale Member directly overlies the Brickkeys (Thompson 1991).

On the outcrop in Missouri, the Plattin thickens southeastward from about 270 feet in northern Perry County to 440 feet in Scott County. A map by Willman et al. (1975, p. 66) shows the Platteville Group (Plattin and Pecatonica) thickening southeastward in the subsurface of Illinois to more than 600 feet. The lower contact is conformable or slightly disconformable. Templeton and Willman (1963, p. 80) stated that a "prominent diastem" occurs at this horizon in Illinois.

Decorah Formation The Decorah Formation is a thin unit that is combined with the Pecatonica and Plattin Formations on the geologic map (plate 1). Although Thompson (1991) classifies the Decorah as a group and Kolata et al. (1986) classify it as a subgroup, this unit is barely thick enough to be a formation in southeastern Missouri. The Decorah was combined with the Plattin on several of the 1:24,000 geologic maps used as sources for this compilation.

In southeastern Missouri, the Decorah is composed of interbedded argillaceous limestone and calcareous shale, commonly divisible into

three units. The lower unit (Castlewood) is gray to brown, slightly argillaceous lime mudstone to fine grainstone that has thin wavy to nodular bedding. The overlying shale (Glencoe) is green to brown and contains thin interbeds of dark gray to purple, highly fossiliferous limestone. The upper limestone (Kings Lake) is argillaceous, silty and dolomitic, finely crystalline, and it occurs in thin slabby beds (Thompson 1991). Brachiopods are abundant in the Decorah. Among them are *Sowerbyella punctostriata*, *Rafinesquina trentonensis*, *Pionodema subaequata*, and *Doleroides gibbosus* (Thompson 1991).

Two regionally mappable K-bentonite beds serve as time markers in the Decorah. They are the Deicke K-bentonite Bed at the base, and the younger Millbrig K-bentonite Bed. Tracking these beds southward shows that the Decorah changes facies from shale to limestone (Kolata et al. 1986, Thompson 1991). In parts of Scott and southern Cape Girardeau Counties, the Decorah is difficult to distinguish from the Plattin.

The Decorah is generally 10 to 30 feet thick in most of the study area. It thins southward as the lower part grades to limestone similar to that of the Plattin.

Kimmswick Limestone The Kimmswick Limestone is equivalent to most of the Galena Group in northern Illinois and is commonly called the "Trenton" in subsurface. In the Paducah 1° × 2° Quadrangle, the Kimmswick crops out in a narrow, curving belt that extends from near Wittenberg, Perry County, Missouri, southward through Cape Girardeau to Thebes, Illinois. Small inliers and outliers occur along faults east and west of the main line of outcrops (plate 1).

The Kimmswick is a readily identified unit of white, light gray and pink, medium to coarse grained crinoidal grainstone. Brachiopods, bryozoans, and corals are abundant. The "sunflower coral" *Receptaculites oweni* is characteristic (Martin et al. 1961). The limestone is thick bedded to massive and commonly crossbedded. Weathered surfaces are pitted and honeycombed. Thin beds of sandstone and chert nodules occur locally. The upper part of the Kimmswick tends to be darker and finer

grained than the lower part, and is slightly cherty. The Kimmswick has been dolomitized in places along the Ste. Genevieve Fault Zone.

The Kimmswick is 50 to 165 feet thick in outcrops in Missouri, and of similar thickness in the subsurface in Illinois (Willman et al. 1975, p. 73). No thickness trends are apparent within the Paducah Quadrangle. The Kimmswick-Decorah contact is disconformable (Kolata et al. 1986, p. 4).

Cincinnatian Series

Cape Limestone Named for Cape Girardeau by Templeton and Willman (1963, p. 134), the Cape Limestone is classified as a formation even though in most places it is too thin to delineate on maps 1:24,000 or smaller. The Cape was combined with the overlying Maquoketa Formation on most source maps and on the map (plate 1) in this report. Thus, the Cape apparently does not meet the test of mappability the North American Stratigraphic Code (1983, Article 24) mandates for a valid formation. The Cape should be reclassified as a member of either the Maquoketa above or the Kimmswick below. Lithologically the Cape appears more closely related to the Kimmswick than to the Maquoketa. A formal reclassification is not proposed in this report, pending further study.

The Cape is a medium to dark brownish gray, medium to coarse grained limestone composed of shell and echinoderm fragments in sparry calcite cement (skeletal grainstone). The Cape is more argillaceous than the Kimmswick, and its fossil fragments are smaller and more rounded. Thickness is 20 feet in parts of the Thebes Quadrangle, but elsewhere the Cape is less than 6 feet thick and discontinuous. The Cape-Kimmswick contact is "welded" and disconformable (Howe and Koenig 1961, Templeton and Willman 1963, Thompson 1991). The age of the Cape is Maysvillian or middle Cincinnatian (Thompson 1991).

Maquoketa Formation The Maquoketa is a dominantly clastic interval overlain and underlain by carbonate rock. Originally classified as a formation (Maquoketa Shale), the unit was elevated in rank to a group both in Illinois (Templeton and Willman 1963, Willman et al.

1975, p. 89) and Missouri (Thompson 1991). This change of rank was inappropriate because several constituent units (formations) are too thin to map separately at commonly used map scales. On source maps of the study area, the Maquoketa was mapped either as a single unit or divided into two or more informal subgroups. It is shown as a single unit on the Paducah bedrock geologic map (plate 1).

In accordance with the North American Stratigraphic Code, the Maquoketa Group in the Paducah Quadrangle has been revised back to a formation, and its constituent formations are reduced to members (Nelson et al. 1995).

The outcrop of the Maquoketa lies just east of the Mississippi River in Alexander County, Illinois, and then crosses into Missouri north of Cape Girardeau and curves away from the river into Perry County. Small inliers and outliers occur east and west of the main belt of exposure (plate 1).

Members of the Maquoketa Formation in the study area are Cape La Croix Shale, Thebes Sandstone, Orchard Creek Shale, and Girardeau Limestone.

The *Cape La Croix Shale Member* (Thompson 1991) is dark greenish, bluish, or brownish gray calcareous clay shale. The shale commonly weathers to a gumbo clay. Thin beds and lenses of light bluish gray, argillaceous limestone are present. The lower contact to the Cape or Kimmswick Limestone is disconformable. The Cape La Croix is 10 to 60 feet thick in outcrops and shallow drill holes near the outcrop; it thickens eastward to as much as 150 feet in the subsurface to Pulaski County, Illinois. The Cape La Croix appears to thicken at least partly at the expense of the overlying Thebes Sandstone.

The *Thebes Sandstone Member*, 20 to 70 feet thick, is greenish to brownish gray and varies from siltstone to fine grained argillaceous sandstone. It is partly calcareous and contains linguloid brachiopods. The Thebes thins northward and intertongues with overlying and underlying shales. The lower contact is locally disconformable.

The *Orchard Creek Shale Member* somewhat resembles the Cape La Croix Shale in lithology. The Orchard Creek is composed of green-

ish, bluish, or olive gray, soft, fissile, calcareous clay shale and silty shale. Nodules and interbeds of limestone are uncommon in the lower part and increase in abundance upward. This limestone is dark colored, dense, argillaceous lime mudstone, like that of the overlying Girardeau Limestone. The Orchard Creek-Girardeau contact is transitional and apparently is intertonguing (Satterfield 1971). The Orchard Creek is 15 to 60 feet thick in outcrops and shallow wells near the outcrops; it thickens to as much as 100 feet in the subsurface of Pulaski County, Illinois, as the Girardeau Limestone grades eastward to shale. The Orchard Creek contains conodonts, graptolites, and crinoids that indicate Richmondian (late Cincinnati) age (Satterfield 1971, Thompson 1991).

The uppermost unit in the Maquoketa is the *Girardeau Limestone Member*. The Girardeau is composed of medium to dark gray and olive gray lime mudstone, in regular thin, wavy, and lenticular beds. Shale interbeds and laminae are common in the lower part, diminishing upward. Nodules of dark gray chert are common in the upper part of the Girardeau. Fossils are uncommon, but show excellent preservation. Among them are crinoids, carroids, erdriosteroids, and trilobites. The age of the Girardeau is late Richmondian (Satterfield 1971). In outcrops, the Girardeau thins northward from 33 feet at the type locality (Cape Girardeau) to less than 10 feet. Eastward in the subsurface the Girardeau apparently grades laterally into shale of the subjacent Orchard Creek.

A discrepancy exists in mapping the Girardeau Limestone. Weller and Ekblaw (1940) and Pryor and Ross (1962) regarded the Girardeau as Silurian and combined it with younger rocks in mapping in Illinois. In Missouri the Girardeau has been mapped with the Maquoketa. From studies of conodonts, Satterfield (1971) and Thompson and Satterfield (1975) established very late Ordovician as the age of the Girardeau. Inclusion of this limestone with the shale-dominated Maquoketa is debatable on lithologic grounds. In any case, the discrepancy is insignificant at the scale of the map in this report.

Total thickness of the Maquoketa on the outcrop is about 100 to 150 feet. Eastward in Illinois, the Maquoketa thickens to more than 300 feet in subsurface (Willman 1975, p. 82).

Leemon Formation A thin, discontinuous limestone that unconformably overlies the Maquoketa Formation previously was called the Edgewood Limestone and assigned to the Silurian System. Thompson and Satterfield (1975) renamed this unit the Leemon Formation and determined its age to be late Richmondian on the basis of conodonts. The Leemon does not meet the test of mappability the North American Stratigraphic Code (1983) stipulates for a valid formation; it should be revised to the rank of member. It was combined with the Maquoketa in the Jackson Quadrangle (Amos 1987c), but was mapped with Silurian rocks in the Cape Girardeau Northeast Quadrangle (Middendorf et al. 1989). The Leemon is so thin that the discrepancy is undetectable at the scale of the map in plate 1.

The Leemon is composed of oolitic limestone, interbedded with shale and siltstone. The limestone is gray to brown, medium grained, and commonly crossbedded. Phosphatic pebbles and clasts of limestone eroded from the Girardeau are common near the base of the Leemon. Mud cracks and intraformational conglomerates are also common and indicate intermittent exposure, possibly on tidal flats. The Leemon is a discontinuous unit less than 25 feet thick, but regionally it is widespread. It lies disconformably on either the Girardeau Limestone or the Orchard Creek Shale Member of the Maquoketa.

SILURIAN SYSTEM

On the geologic map (plate 1), the Sexton Creek Limestone and Bainbridge Formation (comprising the St. Clair Limestone and Moccasin Springs Members) were combined into a single unit. As noted above, the Ordovician Leemon Formation and Girardeau Limestone were combined with Silurian strata in some areas of the Paducah 1° × 2° Quadrangle. The Leemon and Girardeau are so thin that the discrepancy is insignificant at the scale of the map in plate 1.

Silurian strata, as defined above, crop out near the Mississippi River in Alexander and Union Counties, Illinois, and Cape Girardeau and Perry Counties, Missouri. Small fault-bounded inliers and outliers occur east and west of the main strip of outcrops. Thickness of the interval in outcrop ranges from as little as 110 feet in the Jackson Quadrangle to about 190 feet near Thebes, Illinois. The interval thickens eastward in subsurface to more than 500 feet in southern Massac County, Illinois (Whitaker 1988).

Alexandrian Series

Sexton Creek Limestone The Sexton Creek is a unit of brownish gray lime mudstone to skeletal wackestone that contains scattered fossils, including echinoderm, calymenid trilobites, and corals of *Favosites* sp. Bands and lenses of bluish gray, black, and caramel colored chert are prominent through the formation. Thickness in the outcrop belt increases from about 15 feet in the south to about 65 feet in the north. The St. Clair thickens farther in the subsurface to as much as 125 feet in Franklin County, Illinois (Willman et al. 1975). The lower contact is disconformable.

Niagaran and Cayugan (?) Series: Bainbridge Formation

In this report, the Bainbridge is classified as a formation containing the St. Clair Limestone and Moccasin Springs Members. Previously, some geologists classified the Bainbridge as a group and the St. Clair and Moccasin Springs as formations. The change of rank was made because the St. Clair is too thin to map in many places (Nelson et al. 1995).

The *St. Clair Limestone Member* is characterized by light gray to reddish gray and chocolate brown micritic limestone containing large, scattered pink to red echinoderm fragments. Limestone beds are a few inches to several feet thick and alternate with thin layers of shale and siltstone. Chert is uncommon. The fauna includes conodonts, ostracods, phosphatic brachiopods, and small coiled foraminifera identified as *Ammodiscus*. Pryor and Ross (1962) reported small bioherms in this unit.

The St. Clair is 12 to 30 feet thick in outcrop, and thickens eastward to

60 feet in the subsurface (Ross 1964). The lower contact is slightly disconformable.

The McClure Limestone, shown on the map and stratigraphic column of Satterfield (1973), is the same as the St. Clair. The name McClure should be rejected because no published description seems to exist, and the name St. Clair has priority.

The *Moccasin Springs Member* is composed of about 60% to 75% limestone and 25% to 40% shale. The limestone is mottled and variegated brick red to greenish gray, very argillaceous to silty lime mudstone. The shale is red to green, calcareous, and silty; locally it grades to siltstone. The proportion of shale in the formation generally increases toward the top. Fossils include ostracods, foraminifera, graptolites, horn corals, large nautiloids, and crinoid columnals.

At the top of the Moccasin Springs is an interval of greenish gray calcareous siltstone and silty shale. Rogers (1972) proposed assigning this rock to a new formation, the Randol Shale; but other geologists regard this shale as part of the Moccasin Springs, or as the Moccasin Springs-Bailey transition zone.

The Moccasin Springs Member is 60 to 200 feet thick in outcrop and in subsurface. The thickness increases toward the north and east. The lower contact is gradational.

SILURIAN (?) AND DEVONIAN SYSTEMS Tamms Group

The name Tamms group of Rogers (1972) is used informally in this report for the interval of light colored, cherty limestone and bedded chert that overlies red and green limestones and shales of the Bainbridge Formation and underlies slightly cherty limestones of the Muscatatuck Group. The name Tamms (Rogers 1972, p. 64-65) refers to the village of Tamms, Alexander County, Illinois. No type section has been designated; Rogers stated that the group is well exposed in the bluffs northwest of Tamms.

In the Paducah 1° × 2° Quadrangle, the Tamms group contains four formations: Bailey Limestone (oldest), Grassy Knob Chert, Backbone Limestone, and Clear Creek Chert. Lithologic similarity, gradational or

intertonguing relationships, deep residual weathering, and loess cover render these formations difficult to differentiate. The formations have been mapped inconsistently by various geologists; hence, the Tamms group is shown as a single unit on the map (plate 1) in this report.

The definition of the Tamms group used herein differs slightly from Rogers' definition. Rogers included in the Tamms group the Randol Shale, a unit that some geologists regard as part of the Moccasin Springs Member of the Bainbridge Formation. The Randol is gradational to the Moccasin Springs and lithologically similar to other shales within the Moccasin Springs. Mappability of the Randol has not been demonstrated, and the name has not been used outside of Rogers (1972). The Randol is, therefore, considered herein to be a part of the Moccasin Springs Member and excluded from the Tamms group.

The New Harmony Group (Becker and Droste 1978, p. 4) in Indiana includes the Grassy Knob, Backbone, and Clear Creek Formations. Becker and Droste assigned the Bailey Limestone to the Bainbridge Group. Discussions by Becker and Droste and by Shaver et al. (1986, p. 9, 102) indicate that their assignment of the Bailey to the Bainbridge Group is based on the inferred Silurian age of the Bailey rather than on lithologic relationships. The North American Stratigraphic Code (1983) defines groups as lithostratigraphic units and stipulates that age of the rocks is not a valid defining criterion. For this reason, I have chosen to adopt the Tamms group rather than attempt to redefine the improperly defined New Harmony Group.

In the study area, the Tamms group crops out in large areas of eastern Perry County, Missouri, and western Alexander and Union Counties, Illinois (plate 1). Small exposures also occur in fault slices west and northwest of the main area of exposures, and at the apex of Hicks Dome in Hardin County, Illinois (too small to show at the scale of plate 1). Rocks of the Tamms group have undergone deep residual weathering and have eroded to steep bluffs cut by sharply incised ravines. Fresh outcrops are rare; most exposures consist of chert blocks and frag-

ments in a matrix of plastic clay. Few accurate well records exist for the area, so thickness of the Tamms group is poorly known. A map by Willman et al. (1975, p. 112) shows the Lower Devonian Series (identical to Tamms group of this report) thinning northwestward from more than 1,200 feet in southern Massac and Pope Counties, Illinois, to none in western Randolph County. The thinning is largely a consequence of erosion prior to deposition of the overlying Muscatatuck Group.

Age of the Tamms group is largely Early Devonian, but strata of Cayugan (latest Silurian) age may occur at the base. The Grassy Knob, Backbone, and Clear Creek Formations are definitely Devonian. Silurian fossils have been collected near the base of the Bailey (Becker and Droste 1978) and Devonian forms have been collected near the top (Collinson et al. 1967).

Bailey Limestone The Bailey is a unit of light gray to yellowish brown siliceous, cherty limestone that is generally micritic. It is dolomitic and argillaceous, becoming silty near the base. Bedding is mostly thin, but thick beds occur in the middle portion. Lenses and bands of dense greenish to bluish gray and black chert are common throughout the Bailey. Interbeds of greenish gray calcareous shale become common near the base. An unnamed unit of white to gray crinoidal limestone occurs at the top of the Bailey in some outcrops and many wells (Collinson et al. 1967). Fossils are sparse; they include trilobites, brachiopods, sponge spicules, chitinozoans, and conodonts. The trace fossil *Zoophycos* is common in the upper part of the Bailey.

The Bailey is estimated to be 250 to 400 feet thick. Its poorly exposed lower contact is reported to be conformable by some geologists (Pryor and Ross 1962, Ross 1963, Nelson et al. 1995) and disconformable by others (Amos 1985a, 1985c, and 1986a).

Grassy Knob Chert In outcrops, the Grassy Knob is composed almost entirely of white to light gray bedded chert that weathers to yellow, orange, and red. Some intervals of chert are dense and novaculitic, others are brecciated, and still others are porous "popcorn" chert riddled

with horizontal burrows. Locally in Alexander County, Illinois, the Grassy Knob has been altered to tripolitic chert. Fossils are practically nonexistent. The Grassy Knob is more thickly bedded than the Bailey below, or the Clear Creek above.

Sample logs of wells in southern Illinois indicate that the Grassy Knob in subsurface consists of bedded chert, intercalated with lesser amounts of light gray, micritic to finely crystalline, cherty limestone and dolomite.

The Grassy Knob is about 175 to 300 feet thick in the outcrop belt. It appears to thicken southward. The contact to the Bailey Limestone is gradational.

Backbone Limestone The Backbone Limestone was named in Jackson County, Illinois, by Savage (1920), and the Little Saline Limestone was named in Ste. Genevieve County, Missouri, by S. Weller and St. Clair (1928). Subsequent studies (Croneis 1944, Collinson et al. 1967) demonstrated equivalence of the Backbone and Little Saline. Although the name Backbone has priority, geologists in Missouri continue to use the name Little Saline.

The Backbone characteristically is a white to light pinkish gray, fine to very coarse grained crinoidal grainstone that contains bryozoans and brachiopods. It is thick bedded and contains variable amounts of chert. South of Jonesboro, Illinois, the formation has not been positively identified, although Weller and Ekblaw (1940) reported chert float typical of the Backbone. Northward, the unit is as thick as 200 feet. The lower contact is poorly exposed, and may be gradational to slightly disconformable.

Clear Creek Formation The unit is generally called the Clear Creek Chert in published reports, but the name Clear Creek Formation is used herein because in many outcrops and most subsurface sample logs the formation consists largely of carbonate rock; chert is a subordinate lithology. Studies by Berg and Masters (1994) and Nelson et al. (1995) indicate that much of the chert and silica in the Clear Creek and other formations of the Tamms group is a product of secondary alteration of likely hydrothermal origin. Much of the

outcrop belt of the Clear Creek in southwestern Illinois happens to lie in the zone of alteration. Outside of the zone of alteration, the Clear Creek Formation is a cherty limestone or dolomite.

The unaltered Clear Creek Formation is composed of light gray to light brownish gray, siliceous, partly dolomitic lime mudstone. Bedding generally is thin and wavy to lenticular. Chert occurs as nodules and discontinuous layers, and typically constitutes one-fourth to one-third of the rock volume. The chert is white to light gray, slightly mottled, and resembles unglazed porcelain. The Clear Creek is sparingly fossiliferous; strophomenid and spiriferid brachiopods, trilobites, and echinoderm fragments are the fossils usually encountered.

In much of Union and Alexander Counties, Illinois, the Clear Creek has been altered to bedded chert and siliceous rock. Bedded chert from the Clear Creek differs from the Grassy Knob Chert in that it is more thinly bedded, contains vertical rather than horizontal burrows, and contains fairly common fossils (Nelson et al. 1995). A commercially important variety of silica derived from the Clear Creek is tripoli, a white, soft, friable, nearly massive form of microcrystalline silica. Tripoli occurs in lenses or layers as thick as about 20 feet, and is produced from surface and underground mines in Alexander County.

The Clear Creek thickens southeastward from 175 feet in the Altenburg Quadrangle, Missouri, to as much as 600 feet in Illinois. The lower contact is disconformable (Weller and Ekblaw 1940).

Middle Devonian Series: Muscatatuck Group

The Muscatatuck Group was defined by Shaver (1974) as an interval of partly argillaceous and sandy limestones that unconformably overlies the Clear Creek Chert and older strata and underlies the New Albany Shale. The name Muscatatuck Group is hereby extended to the Paducah Quadrangle without modification. Formations within the Muscatatuck Group are not mapped consistently in the report area, and their names change at state lines. The Muscatatuck Group is delineated as a single unit on plate 1.

The Muscatatuck Group is predominantly Middle Devonian, but the basal part may be late Early Devonian (Shaver 1984, Shaver et al. 1986).

The Muscatatuck Group crops out in a narrow strip that runs southward through Union, Alexander, and Pulaski Counties, Illinois (plate 1). It was also identified in fault slices in the Ste. Genevieve Fault Zone and at the apex of Hicks Dome, Hardin County, Illinois (plate 1). Thickness of the group is quite variable. In southwestern Illinois, it thickens northward from 20 feet to about 200 feet. It is about 250 feet thick at Hicks Dome and 400 feet thick in Perry County, Missouri, south of the Ste. Genevieve Fault Zone. North of the Ste. Genevieve Fault Zone, the group was eroded or never deposited. In the subsurface of parts of southeastern Illinois, the Muscatatuck Group is more than 300 feet thick (North 1969).

Grand Tower Limestone The Grand Tower Limestone is called the Jeffersonville in Indiana and Kentucky. In its type area of southwestern Illinois, the Grand Tower is dominantly light to medium gray, fine to coarse grained, sandy, and fossiliferous limestone. In the lower part of the Grand Tower, the limestone is dominantly light gray, coarse crinoidal grainstone that grades upward to darker gray, finer grained skeletal packstone and wackestone. Lenses and interbeds of white, well sorted, and well rounded quartz sandstone occur at various positions in the formation. The most persistent is the basal Dutch Creek Sandstone Member, which is as thick as 45 feet. The fauna of the Grand Tower includes echinoderms, brachiopods, gastropods, corals, stromatoporoids, and bryozoans.

The Grand Tower is 150 to 230 feet thick in fault slices along the Ste. Genevieve Fault Zone and about 150 feet thick at Hicks Dome. It thins rapidly southward in the outcrop belt. In Alexander and southern Union Counties, Illinois, only the Dutch Creek Member is present. As a consequence of uplift of the northern block of the Ste. Genevieve Fault Zone during Middle Devonian time, the Grand Tower was not deposited, or was eroded from most of the area north of the fault zone.

The lower contact of the Grand Tower is a prominent unconformity adjacent to the Ozark Dome (Meents and Swann 1965). In the deep part of the Illinois Basin, however, this contact probably is conformable (Collinson et al. 1967).

St. Laurent Formation The carbonate unit overlying the Grand Tower Limestone in southwestern Missouri was named the St. Laurent Formation (Wilson 1922, S. Weller and St. Clair 1928). In Illinois most geologists used the names Lingle Limestone and Alto Formation (Savage 1920) for the same strata. New mapping in southwestern Illinois (Nelson et al. 1995) shows that the Lingle Limestone and Alto Formation cannot be differentiated reliably, in part because of inadequate definition and complex facies relationships. Accordingly, Nelson et al. (1995) formally abandoned the names Lingle Limestone and Alto Formation, and extended use of the name St. Laurent Formation into Illinois. The St. Laurent is equivalent to the Sellersburg Limestone in Kentucky and the North Vernon Limestone in Indiana.

The St. Laurent Formation is composed chiefly of limestone, interbedded with lesser amounts of dolomite, shale, siltstone, and chert. The limestone is generally darker gray, finer grained, and more argillaceous than the Grand Tower Limestone. The St. Laurent is thin to medium bedded and silty to sandy. It contains numerous lenses and bands of brown chert, especially in the upper part. Corals, brachiopods, gastropods, pelecypods, and crinoids are common. The "button coral" *Microcyclus* discus is diagnostic for the basal St. Laurent. Other features include stromatoporoids, intraformational breccia, phosphatic material, and oolitic limestone. Dark brownish gray dolomite is present in the upper portion of the unit. Carbonate rocks are intercalated with dark olive gray and brownish gray calcareous shale and siltstone.

The St. Laurent Formation reaches a maximum thickness of approximately 200 feet in fault slices along the Ste. Genevieve Fault Zone in Perry County, Missouri. The St. Laurent is absent from most of the area north of the fault zone, a consequence of Middle Devonian uplift

and erosion or nondeposition (plate 2, section A-B). In the subsurface of southern Illinois, the St. Laurent Formation is absent in southern Pulaski County; however, it is as thick as 100 feet in parts of Union and Gallatin Counties (North 1969). The upper part of the St. Laurent intertongues with and grades eastward into the lower part of the overlying New Albany Shale in southwestern Illinois (North 1969). The contact of the St. Laurent to the Grand Tower Limestone is either conformable or a minor disconformity (Meents and Swann 1965, North 1969).

New Albany Shale The name New Albany Shale is used in this report for the interval of dark colored, organic shale that overlies the Muscatatuck Group and underlies the Chouteau (Rockford) Limestone. The New Albany was originally defined by Borden (1874, p. 158-60) on the basis of exposures at New Albany, Indiana. Some geologists in western Kentucky, including Rogers (1963) and Amos and Finch (1968), applied the name Chattanooga Shale to the same interval of rocks. Also, the term Mountain Glen Shale appears in older reports on southwestern Illinois and southeastern Missouri. As Workman and Gillette (1956, p. 38-39) pointed out, the term New Albany has priority of usage and is more inclusive than the term Chattanooga or Mountain Glen. New Albany is, therefore, the name of choice for this report.

The New Albany carries the rank of formation in Indiana, Kentucky, and Missouri, but it has been classified as a group in publications of the Illinois State Geological Survey since the early 1960s. Apparently, no explanation for elevating the rank of the New Albany was published. The term New Albany Shale Group first appeared in Swann and Willman (1961), but several later ISGS reports, including Ross (1963, 1964) and Swann et al. (1965), classified the unit as a formation. The name of the unit in Illinois was formally changed back from New Albany Group to New Albany Shale by Nelson et al. (1995).

The New Albany was mapped and described as a single unit in the Paducah Quadrangle by all outcrop mappers. Working with subsurface data, Cluff et al. (1981) defined the

New Albany as a group, comprising nine formations recognized in various parts of Illinois. The "formations" in southern Illinois are shales distinguished chiefly on the basis of geophysical log properties. Cluff et al. (1981) characterized these shales as being lithologically similar, vertically gradational, and laterally intertonguing. They are better designated as members, beds, or facies than as formations. Accordingly, the New Albany Shale herein is ranked as a formation throughout the Paducah Quadrangle.

The New Albany crops out at several scattered localities. In Kentucky, it occurs in small fault slices near Kuttawa, Lyon County, and Calvert City, Marshall County (plate 1). In southeastern Illinois the New Albany is exposed at Hicks Dome and at the "Horseshoe upheaval," a fault slice 14 miles north of Hicks Dome (plate 1). Outcrops in Missouri are confined to fault slices in the Ste. Genevieve Fault Zone (plate 1). The largest area of New Albany outcrops is a strip that trends slightly south of east through Union, Alexander, and Pulaski Counties, Illinois (plate 1).

The New Albany Shale is greenish gray to olive gray, dark gray, and brownish black. It is well indurated, moderately to well laminated, and fissile. Portions are calcareous or dolomitic, and phosphatic nodules are common. Laminae of silt and scattered sand grains are present. The organic carbon content is as high as 15% in the black shales (Cluff et al. 1981). Fossils include fish remains, conodonts, small brachiopods, *Tasmanites*, and a variety of trace fossils (Cluff et al. 1981).

North of the Ste. Genevieve Fault Zone, the New Albany lies unconformably on rocks as old as Cincinnati (Late Ordovician). The unconformity reflects Late Devonian tectonic movements. Southeastward, the contact becomes conformable, and the lower part of the New Albany is in facies relationship to the Lingle Limestone (North 1969).

The New Albany is thin or absent in the northwestern part of the quadrangle, and thickens to a maximum of 460 feet in the southeastern part (Cluff et al. 1981, Schwalb and Potter 1978).

Age of the New Albany ranges from late Middle Devonian through

early Kinderhookian (Mississippian) (Cluff et al. 1981).

MISSISSIPPIAN SYSTEM

Kinderhookian Series

The Kinderhookian Series in the study area is represented by the uppermost part of the New Albany Shale and by the Chouteau Limestone. In Missouri, the Bushberg Sandstone and Bachelor Formation may be present (Thompson 1986), but they have not been recognized at the surface.

The Chouteau Limestone, called the Rockford Limestone in Kentucky, is widely present in the study area but is less than 8 feet thick. This unit can be identified in many well records but outcrops are rare; it was combined with other units in mapping. Lithologically, the Chouteau is described by Workman and Gillette (1956, p. 32–33) as light greenish gray and light to dark brownish gray, sublithographic limestone (lime mudstone) containing coarse crinoid fragments. It is partly dolomitic and argillaceous to silty. The lower contact is either conformable or slightly disconformable.

Valmeyeran Series

The Valmeyeran Series, as recognized by the Illinois and Indiana Geological Surveys, is equivalent to the combined Osagean and Meramecian Series recognized by the Missouri and Kentucky Geological Surveys. This interval is characterized by major facies changes, inconsistently defined formations, and nomenclature that changes at state boundaries. Differences among the many source maps created unresolvable inconsistencies on plate 1. For purposes of discussion, three basic units can be recognized (fig. 2).

- Lower Valmeyeran carbonate-bank rocks, which occur only in the northwestern part of the Paducah Quadrangle.

- Lower Valmeyeran clastic rocks, which occur throughout the quadrangle and overlap Osagean carbonate rocks.

- Upper Valmeyeran carbonate rocks, which are assigned to the Mammoth Cave Group and overlies the lower Valmeyeran clastic rocks throughout the study area.

Carbonate-bank rocks An interval of lower Valmeyeran limestone, interpreted as a crinoidal carbonate bank by Lineback (1966), was mapped in the northwest quarter of the study area. Outcrops are confined to the vicinity of the Ste. Genevieve Fault Zone in Missouri (plate 1), but the rocks also occur in the subsurface of Missouri and Illinois north of the fault zone. The constituent formations are the Fern Glen Formation (oldest), the Burlington Limestone, and the Keokuk Limestone (fig. 2). These formations are not assigned to any group, although a group name would be useful.

The *Fern Glen Formation* is largely limestone, interbedded with lesser amounts of dolomite, shale, and chert. Carbonate rocks are mostly light to medium yellowish brown, finely to coarsely crystalline, and medium to thick bedded. Fossils include crinoids, brachiopods, bryozoans, and corals. Shale in the Fern Glen is greenish to brownish gray and occurs in greatest abundance near the base of the unit. Brown chert lenses and layers and small quartz geodes are common. The Fern Glen varies from 50 to 160 feet thick across short distances. North of the Ste. Genevieve Fault Zone, the Fern Glen unconformably overlies rocks as old as Ordovician (Maquoketa Formation). The Fern Glen may rest conformably, however, in places on thin, unrecognized Kinderhookian strata, which in turn unconformably overlie older rocks.

The *Burlington Limestone* is white to light brownish gray, medium to very coarse bioclastic and oolitic calcarenite. It is mostly thick bedded to massive and contains abundant bands and nodules of white to light gray chert. Occasional thin beds of gray calcareous shale are present, especially in the lower part. The Burlington is 85 to 125 feet thick in outcrops in the Belgique and Lithium Quadrangles, Missouri, and reaches 300 feet thick in the Altenburg Quadrangle. It grades into the Fern Glen.

The *Keokuk Limestone* resembles the Burlington, into which it grades. The Keokuk tends to be light brown rather than white or gray, and it contains beds of fine grained dolomite, especially near the top. Crinoids,

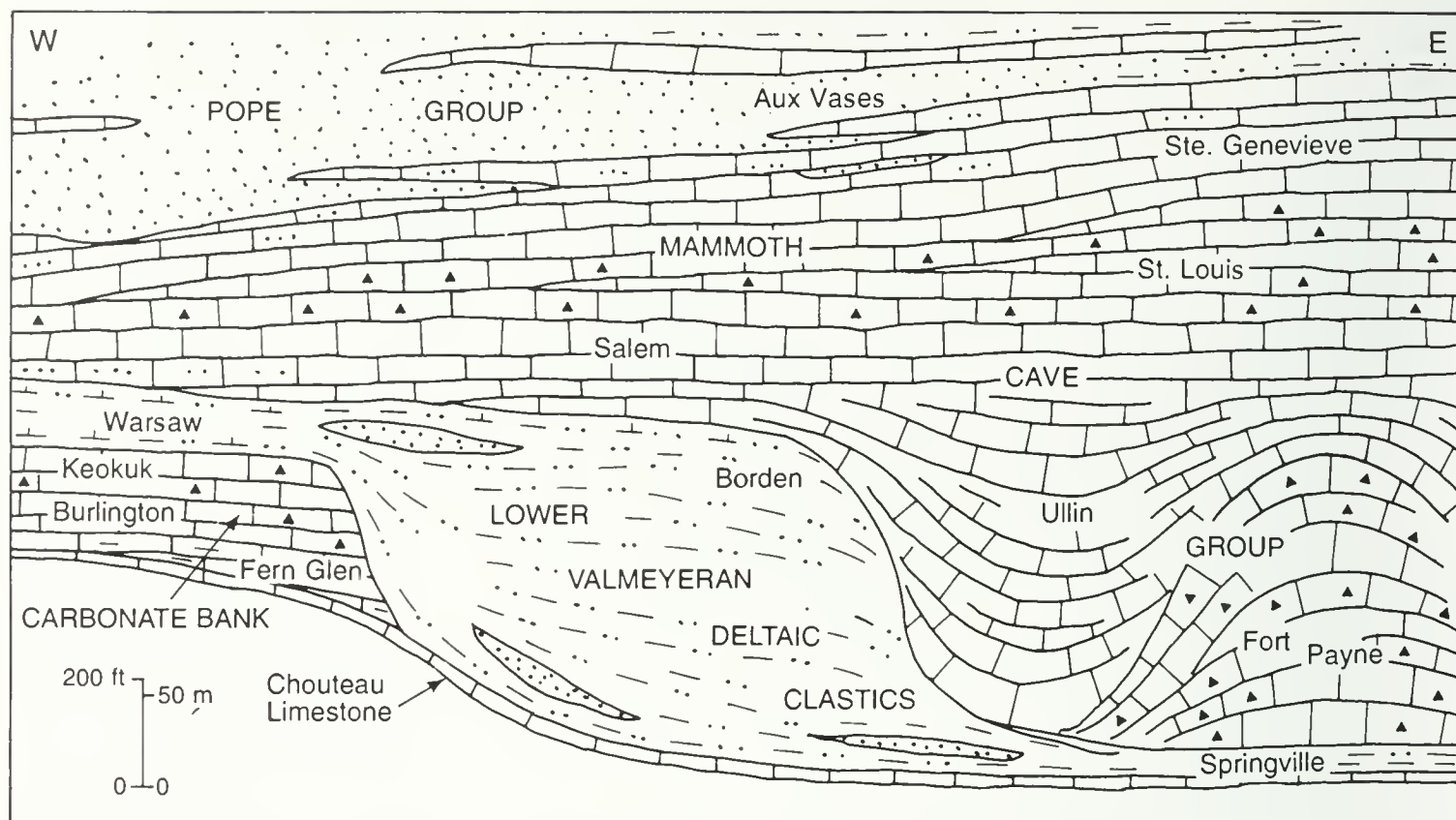


Figure 2 Relationships of lower and middle Mississippian rocks in the study area (after Lineback 1968 and Treworgy 1991).

brachiopods, and corals are common. The Keokuk tends to be less cherty than the Burlington. Thickness of the Keokuk is 75 to 120 feet in the Missouri portion of the Paducah Quadrangle.

Lower Valmeyeran deltaic clastic rocks Lower Valmeyeran shale and siltstone of deltaic origin overlie Kinderhookian strata in the eastern half of the Paducah Quadrangle, and overlap the Osagean limestones described above in the northwest (fig. 2). Three formations, not currently assigned to any group, are essentially facies of one another. The formations are the Springville (New Providence) Shale, Borden Siltstone, and Warsaw Formation.

The *Springville Shale* was combined with the overlying Fort Payne Formation on the geologic map (plate 1). In Kentucky, it is called the New Providence Shale. The Springville is a unit of greenish to olive gray and brownish gray clay shale and silty shale. The shale generally coarsens upward, has indirect lenticular bedding, and contains a few burrows, but rare body fossils. In southwestern Illinois, the upper part of the Springville is a highly siliceous, blocky mudstone that weath-

ers to variegated red, gray, and brown fragments called "calico rock." The Springville ranges from a few feet to about 60 feet thick, and the lower contact is disconformable (Weller and Ekblaw 1940).

The *Borden Siltstone* does not crop out within the Paducah Quadrangle, but it is as thick as 290 feet in wells in the north-central part of the area. Lineback (1966, 1981) described the Borden in Illinois as gray to brownish gray argillaceous siltstone, with lesser amounts of silty shale, fine sandstone, and light colored fossiliferous sandstone. The siltstone is partly calcareous and glauconitic.

The *Warsaw Formation* overlies Osagean limestones in the northwestern part of the quadrangle. It was combined with the overlying Salem Limestone on source maps and had to be depicted thus on the Paducah bedrock geologic map. The Warsaw is dominantly shale north of the Paducah Quadrangle, but it is mapped within the study area to contain as much as three-fourths limestone. The limestone is medium brownish gray, fine to coarse grained calcarenite composed of oolites and fragments of echinoderms, bryozoans, brachiopods, pelecypods, and foraminifera. Shale in

the Warsaw is medium to dark gray and calcareous. Shale occurs throughout the Warsaw, but it is most prevalent near the base. The Warsaw is 130 to 210 feet thick in outcrops in the Paducah Quadrangle. The contact to the underlying Keokuk Limestone is gradational.

Swann et al. (1965) and Lineback (1966) characterized the Borden Siltstone, Springville Shale, and Warsaw Shale as deposits of a delta that prograded into southwestern Illinois from the northeast. Under their model, the Fern Glen–Burlington–Keokuk Limestones represent a carbonate crinoidal bank that existed contemporaneously with early deltaic sedimentation. The Borden Siltstone was interpreted as imbricated bottomset, foreset, and topset beds of the delta. The Springville Shale was interpreted as distal bottomset beds, and the Warsaw Shale as deltaic sediments that overrode the carbonate bank.

Mammoth Cave Group The name "Mammoth Cave Limestone Series" was first used by Miller (1917, 1919) in reference to the interval of relatively pure Mississippian limestone within which Mammoth Cave and other extensive caverns of

western Kentucky are developed. As defined by Miller, the Mammoth Cave contained the St. Louis and Ste. Genevieve Limestones. The name Mammoth Cave lapsed into infrequent and informal use until redefined by Swann and Willman (1961) as the Mammoth Cave Megagroup. In that report, the Mammoth Cave is "the entire main body of Mississippian carbonate rocks of the midwest lying above the clastic wedge of the Knobs Megagroup and beneath the lowest well-developed sandstone or shale of late Meramecian or Chesterian age (p. 481)."

Swann and Willman showed that both upper and lower boundaries of the Mammoth Cave are time-transgressive in response to lateral facies changes across the Illinois Basin. They indicated the Chouteau Limestone as the lowest unit of the Mammoth Cave in western Illinois; eastward the boundary steps up to the base of the Fort Payne or Ullin Formation. Swann and Willman evidently did not recognize that the Warsaw Formation in western Illinois is a lateral facies of the Borden Siltstone and part of the "clastic wedge of the Knobs Megagroup" (Lineback 1966, 1981). In this report, the Mammoth Cave is redefined to contain only the predominantly limestone units that overlie the Warsaw Formation, Borden Siltstone, and Springville Shale (fig. 2). Within the Paducah Quadrangle, the Mammoth Cave comprises, in ascending order, the Fort Payne Formation, Ullin Limestone, "Warsaw" Limestone of Kentucky usage, Salem Limestone, St. Louis Limestone, and Ste. Genevieve Limestone. Because this interval contains formations but no other groups, the rank of the Mammoth Cave is reduced from megagroup (or supergroup) to group.

The upper boundary of the Mammoth Cave Group is the top of the Ste. Genevieve Limestone throughout the Paducah Quadrangle. East of the study area, the upper boundary steps up to include younger limestones, as clastic units above the Ste. Genevieve pinch-out eastward (Swann and Willman 1961).

Strata of the Mammoth Cave Group crop out in large areas of southernmost Illinois and western Kentucky. Descriptions of the formations that make up the group are confusing and often contradictory.

These formations were defined at a time when lithostratigraphic and chronostratigraphic concepts were not sharply separated in the minds of geologists. Consistent subdivision of the Mammoth Cave Group in the Paducah Quadrangle is not possible, using available source maps. The most serious mismatches of contacts occur at the Illinois-Kentucky border (fig. 3).

A good synthesis of the Mammoth Cave Group is found in Cluff and Lineback (1981). The focus of the synthesis is on facies rather than formational nomenclature.

The **Fort Payne Formation** is the oldest unit in the Mammoth Cave Group. On the geologic map (plate 1), the Fort Payne is combined with the Springville Shale.

The Fort Payne is largely dark gray, micritic to fine grained, highly siliceous limestone. Beds 2 to 30 inches thick are separated by thin layers of dark gray to black siliceous shale. Bedded and nodular chert constitutes 10% to 40% of the formation. The Fort Payne weathers deeply to a white, porous, tripolitic residuum containing fragments of chert that have wood grain texture. A unit of as much as 50 feet of gray novaculitic bedded chert in Union County, Illinois, is a weathered or altered phase of the Fort Payne Formation (Nelson et al. 1995). This chert was called the "Hartline Chert" in older reports (e.g., Weller and Ekblaw 1940).

The Fort Payne thickens eastward from a few tens of feet in Union County, Illinois, to more than 600 feet in parts of Livingston, Lyon, and Marshall Counties, Kentucky. The lower contact appears disconformable in Illinois outcrops (Nelson et al. 1995), but it is probably conformable in the subsurface (Lineback 1966).

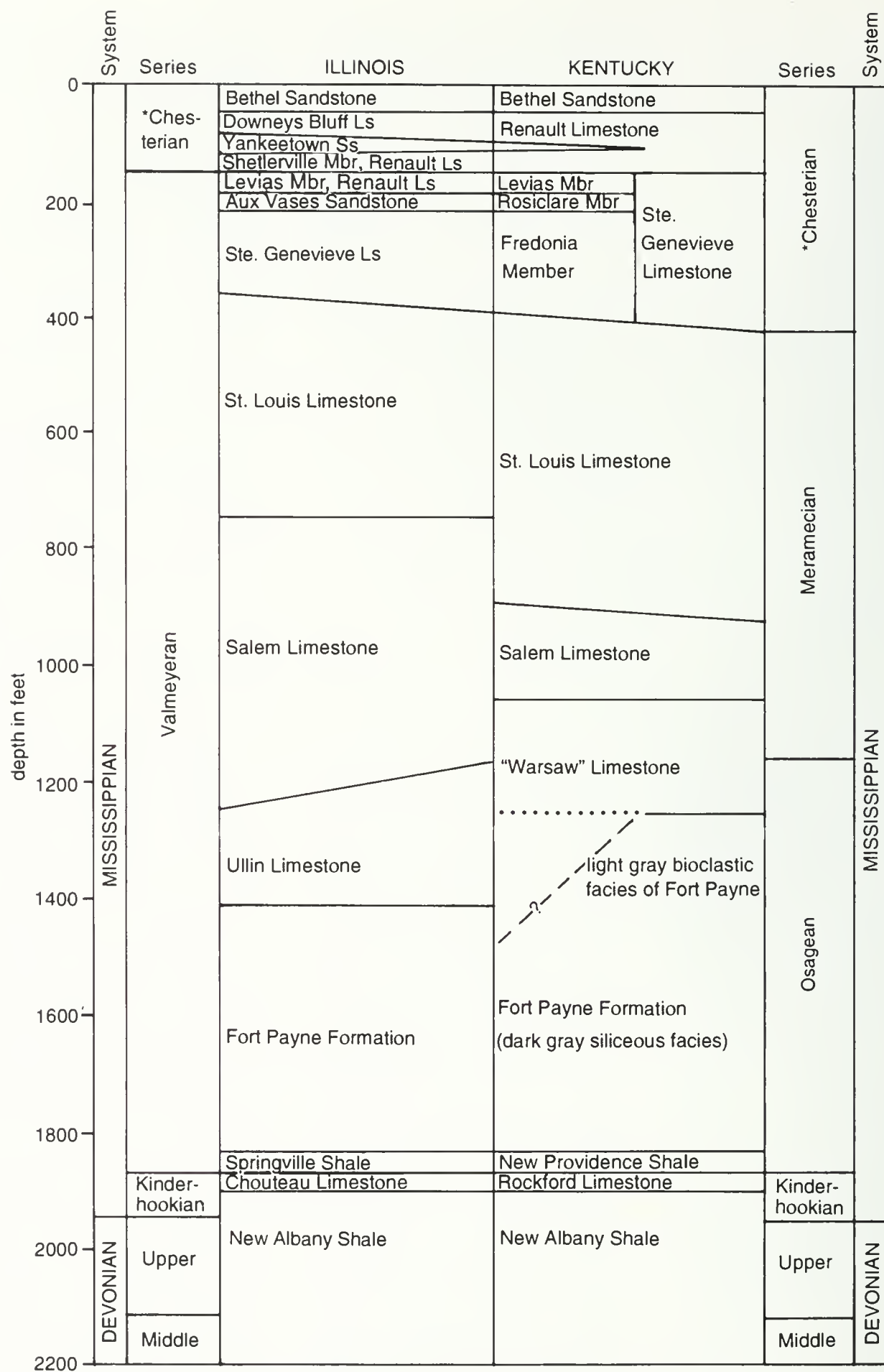
Overlying the Fort Payne in western Kentucky is a unit that has long been called the "**Warsaw**" Limestone. The "Warsaw" in Kentucky is neither correlative nor similar in lithology to the type Warsaw Shale of western Illinois (Sable and Dever 1990, p. 57). The "Warsaw" of Kentucky is a unit of calcarenitic limestone, whereas the type Warsaw Shale is composed of fossiliferous shale containing quartz geodes and interbeds of argillaceous limestone. The type Warsaw is a part of the Bor-

den deltaic clastics, but the "Warsaw" Limestone is part of the Mammoth Cave Group and overlies the Borden clastics. The "Warsaw" Limestone of Kentucky should be renamed; however, such revision will require comprehensive outcrop and subsurface study beyond the scope of this report. For this project, the "Warsaw" was mapped and described as it was on the 7.5-minute geologic quadrangles. The name "Warsaw" is in quotation marks to underscore its questionable status.

The "Warsaw" Limestone in fault blocks of Livingston, Lyon, and Marshall Counties, Kentucky (plate 1), is described as light to medium gray, fine to very coarse grained calcarenite. It is composed of shiny brachiopod and echinoderm fragments in a dull bryozoan-rich matrix. Portions are oolitic and crossbedded. Common fossils include *Fenestella*, *Spirifer lateralis*, and *Echinocrinus*. The lower part of the "Warsaw" is generally darker, finer grained, better laminated, and more cherty than the upper part of the unit. The basal "Warsaw" grades downward into the Fort Payne and may be equivalent to the Ramp Creek Member of the Ullin Limestone in southern Illinois (Lineback 1966). The upper part of the "Warsaw" appears to be equivalent to strata mapped in the lower part of the Salem (fig. 3). As mapped, the "Warsaw" is 180 to 240 feet thick.

The **Ullin Limestone** (Lineback 1966) is similar in lithology and partly equivalent to the "Warsaw" Limestone in Kentucky (fig. 3). The Ullin is mapped in Hardin County, Illinois, where it is combined with the overlying Salem Limestone (plate 1). In southwestern Illinois, the Ullin is mapped separately (plate 1).

The Ullin is largely crinoid-bryozoan grainstone and packstone that are crossbedded, slightly cherty, and lack oolites. The lower part, which Lineback (1966) designated the Ramp Creek Member, is medium brownish gray, fine grained, and moderately cherty limestone that laterally intertongues with the Fort Payne Formation (Nelson et al. 1995). The upper part of the Ullin is nearly white to yellowish gray, medium to very coarse grained, crossbedded limestone that contains little or no chert. The upper part of the



*Chesterian—Valmeyeran boundary on left is according to Swann 1963

Chesterian—Meramecian boundary on right is according to Maples and Waters 1987

Figure 3 Differences in Mississippian stratigraphic nomenclature between southern Illinois and western Kentucky.

Ullin has a distinctive speckled appearance created by tan crinoid fragments in a dull white matrix of bryozoan fragments. Lineback (1966) called the upper Ullin the Harrodsburg Member. Nelson et al. (1995) indicates that "Ramp Creek" and "Harrodsburg" lithologies intertongue on a large scale, and are better regarded as lateral facies than as members in a vertical succession.

The Ullin ranges from 125 to 580 feet thick in outcrops in the Paducah Quadrangle. In the subsurface it thickens to 700 feet in Hamilton County, Illinois (Lineback 1966). The contact to the Salem Limestone is gradational and intertonguing.

The *Salem Limestone* was mapped throughout the Paducah Quadrangle, but it was defined differently in different areas (fig. 3). In Kentucky, the Salem was restricted to 110 to 160 feet of medium to dark gray, finely to coarsely crystalline, partly oolitic and pelletal biocalcarenite overlying the "Warsaw" Limestone. Endothyrid foraminifera are abundant; other common fossils are plates of the echinoid *Melonechinus*, the brachiopod *Echinoconchus*, the blastoid *Pentremites*, the colonial coral *Acrocyathus* (formerly *Lithostrotion*), cup corals, and crinoid fragments. The Salem was combined with the overlying St. Louis Limestone on source maps from Kentucky; in the Kentucky portion of the map area (plate 1), the Salem, St. Louis, and Ste. Genevieve Limestones are shown as a single unit.

In southeastern Illinois, the interval of rocks assigned to the Salem is as thick as 500 feet and includes strata mapped as "Warsaw" and St. Louis in Kentucky (fig. 3). Baxter et al. (1963, 1967) and Baxter and Desborough (1965) described an interval of dark gray to black, fine grained, petroliferous limestone in the upper part of the Salem. Similar beds in Kentucky were mapped as St. Louis (Trace and Amos 1984).

In southwestern Illinois, where the Salem is mapped as a separate unit, the formation contains limestones of diverse lithology. The lower part contains alternating intervals of light gray skeletal and oolitic grainstones and packstones, and darker gray, cherty, and dolomitic wackestones and lime mudstones. The upper part is composed mostly

of medium dark gray, fine to medium grained, thick bedded skeletal packstone that contains scattered oolites. The rugose coral *Acrocyathus proliferus* is abundant in the uppermost beds of the Salem and in the basal part of the overlying St. Louis Limestone. The Salem-St. Louis contact is gradational; it is mapped at the highest occurrence of skeletal packstones below cherty lime mudstones of the St. Louis. Thickness of the Salem in southwestern Illinois is about 300 to 450 feet.

The Salem Limestone and Warsaw Formation are combined into a single unit in Missouri (plate 1). The Ullin Limestone may be present in this area also, but it was not recognized. The Salem in Missouri is described as light gray, medium to coarsely crystalline, bioclastic and oolitic calcarenite (grainstone), commonly crossbedded, and containing thin interbeds of shale. The upper portion tends to be dolomitic. Thickness is reported to be 105 to 175 feet.

Throughout the study area the upper and lower contacts of the Salem Limestone are gradational. The Salem intertongues with the overlying St. Louis (Lineback 1972).

The *St. Louis Limestone* occurs throughout the study area, and is combined with the overlying Ste. Genevieve Limestone on the geologic map. The two units are combined because they are not separated consistently on source maps. The most characteristic lithology is medium to dark gray, sublithographic lime mudstone to finely fragmental limestone that contains numerous lenses and bands of dark gray to black chert. Within the Mammoth Cave Group, only the Fort Payne contains a larger proportion of chert than the St. Louis. Some beds of the St. Louis are dolomitic. The colonial corals *Acrocyathus proliferus* and *A. floriformis* are numerous in the lower St. Louis (Sable and Dever 1990). These corals were called *Lithostrotion proliferum* and *Lithostrotionella castelnaui*, respectively, in older reports. Interbeds of light gray oolitic and skeletal grainstone become increasingly numerous in the upper St. Louis, in transition to the Ste. Genevieve Limestone.

The St. Louis thickens from as few as 75 feet in Missouri to 300 feet in parts of Illinois. The formation is

variously reported to be 275 to 500 feet thick in southeastern Illinois and Kentucky. Part of the thickness variation is due to inconsistent placement of the upper and lower contacts, both of which are gradational and intertongued.

The *Ste. Genevieve Limestone* occurs throughout the study area and is mapped in combination with the St. Louis (and also with the Salem in Kentucky). The most typical lithology is light gray and brownish gray, fine to medium grained oolitic and skeletal grainstone and packstone. This rock is commonly crossbedded and contains quartz sand grains in the upper part. Interbeds of darker, partly dolomitic lime mudstone, similar to the St. Louis, also are present. Chert is light colored and less common in the St. Louis. The Ste. Genevieve contains interbeds of greenish gray calcareous shale and siltstone and light gray to greenish gray, fine grained calcareous quartz sandstone. Common fossils are the distinctive crinoid *Platycrinites penicillus*, the brachiopod *Pugnoides ottumwa*, and gastropods of the genus *Bellerophon*.

The Ste. Genevieve Limestone grades into and probably intertongues with the underlying St. Louis. The upper part of the Ste. Genevieve is in facies relationship with the Aux Vases Sandstone (Pope Group). Clastic beds of the Aux Vases alternate with and grade laterally eastward to limestone beds of the Ste. Genevieve in southwestern Illinois. The interval of intertonguing was called the Hoffner Member in older reports and the Joppa Member by Swann (1963). In southeastern Illinois, the Aux Vases (Rosiclare) Sandstone thins to about 20 feet; sandstone occurs only as isolated lenses (Spar Mountain Member) in the upper Ste. Genevieve. The Rosiclare Sandstone and the overlying Levias Limestone are regarded as members of the Ste. Genevieve in western Kentucky, but the Levias is a member of the Renault Limestone in Illinois (fig. 3). The change in nomenclature reflects eastward thinning of sandstones and facies changes in the limestones.

The Ste. Genevieve is as thin as 45 feet near the northwest corner of the Paducah 1° × 2° Quadrangle. In Illinois and Kentucky, it varies from about 120 to 300 feet thick.

Chesterian Series: Pope Group

The name Chester Group (Worthen 1866) was originally designated as the interval of alternating clastic and carbonate formations overlying the Ste. Genevieve Limestone. The characterization of the Chester Group or Series by subsequent geologists, such as S. Weller (1913, 1920), carried both lithologic and biostratigraphic implications. Swann (1963) established the Chesterian Series as a chronostratigraphic unit, the upper limit of which is defined by the highest stratigraphic occurrence of *Platycrinites penicillus* and the lowest occurrence of crinoids of the genus *Talarocrinus* having smooth, somewhat inflated plates. This boundary corresponds with the top of the Ste. Genevieve Limestone in western Kentucky and the top of the Levias Limestone Member of the Renault Limestone in Illinois. Maples and Waters (1987) proposed revising the Valmeyeran-Chesterian boundary downward to a position near the base of the Ste. Genevieve Limestone. Using an argument that dates back to Ulrich (1905), they contend that the faunal change at the base of the Ste. Genevieve is more significant than the change at the top.

The name Pope Group is used herein for the interval of alternating clastic and carbonate rocks that overlies the Mammoth Cave Group and extends to the top of the Mississippian System. This interval was originally named the Chester Group by Worthen (1866). Swann and Willman (1961) introduced the term Pope Megagroup as a lithostratigraphic unit, to be distinguished from the chronostratigraphic unit Chesterian Series. The name Pope (from Pope County, Illinois) is useful; however, the rank of the unit is hereby reduced from megagroup (supergroup) to group. The North American Stratigraphic Code (1983) does not recognize megagroups, and defines supergroups as units composed of related groups, or related formations and groups. No groups are recognized within the Pope in the Paducah Quadrangle. Several groups that previously were designated within the Pope are reduced in rank to formations in this report because their constituent units are not mappable at scales required for formations.

The lower boundary of the Pope Group is time-transgressive. The boundary rises in a series of steps toward the east as clastic units in the lower part of the Pope Group successively wedge out into limestones of the upper part of the Mammoth Cave Group. The Pope-Mammoth Cave contact is mapped at the top of the Ste. Genevieve Limestone throughout the Paducah Quadrangle. As previously noted, the top of the Ste. Genevieve was mapped at a higher stratigraphic level in Kentucky than in Illinois (fig. 3). The vertical step, about 50 feet, is minor at the scale used on the Paducah compilation map (plate 1).

The Pope Group was divided into numerous formations, most of which are too thin to portray at scales of 1:100,000 or smaller. For this report (plate 1), the Pope Group was informally split into upper and lower units of approximately equal thickness. The boundary between the upper and lower units was placed at the top of the Glen Dean Limestone, a placement that coincides with that on the geologic map of Kentucky (McDowell et al. 1981).

In general, formations of sandstone, siltstone, and silty shale alternate with formations of limestone and clay shale in the Pope Group. Some formations include both limestone and sandstone. In the past, geologists who named formations in the Pope Group tended to emphasize lateral continuity and to downplay or ignore facies and thickness changes. Several formations previously named in the Paducah Quadrangle are not mappable at the surface at a scale of 1:24,000. Such formations are reduced to members in this report. Also, several units previously designated as groups are reduced to formations, and their definitions are restricted to call attention to significant lateral changes in lithology.

The Pope Group has a maximum thickness of approximately 1,400 feet in parts of western Kentucky and southeastern Illinois. Gradual northwestward thinning reflects thinner deposition. Abrupt local thinning of the Pope Group is the result of erosion at the base of the Pennsylvanian System.

The Pope Group crops out extensively in the faulted area of western Kentucky (plate 1), and it extends

westward in an arcuate belt across southern Illinois (plate 1). Outcrops in Missouri are confined to small areas along the Ste. Genevieve Fault Zone (plate 1).

Aux Vases Sandstone The Aux Vases Sandstone, the oldest formation in the Pope Group, occurs throughout the Paducah Quadrangle. In Kentucky, it is called the Rosiclare Sandstone Member of the Ste. Genevieve Limestone (fig. 3). The Aux Vases thickens northwestward from as few as 10 feet in Kentucky to more than 100 feet at places in Perry County, Missouri. Where it is thin, the Aux Vases is composed of light greenish gray, very fine grained, glauconitic sandstone. It is commonly calcareous and contains lenses of sandy limestone and interbeds of greenish gray silty shale. The sandstone is generally thinly bedded and ripple laminated. Northwestward, as it thickens, the Aux Vases grades to white or light gray, fine to medium grained, crossbedded or massive sandstone. Interbeds of gray, greenish gray and red silty shale and siltstone are present, especially near the base.

The lower contact of the Aux Vases is locally disconformable, but it is more commonly gradational. Clastic strata of the Aux Vases inter-tongue with and grade laterally into the Ste. Genevieve Limestone.

Renault Limestone The Renault Limestone originally was defined in Monroe County, southwestern Illinois (S. Weller 1913). The Renault in southeastern Illinois was divided into the Levias Member (older) and Shetlerville Member by Swann (1963). As mapped in western Kentucky, the "Renault" comprises the Shetlerville Member and the overlying Downeys Bluff Limestone, which is not part of the type Renault (fig. 3).

The Levias Member, which is assigned to the Ste. Genevieve Limestone in Kentucky, is 10 to 35 feet thick and is composed of light gray or brownish gray limestone. The texture varies from lime mudstone to oolitic grainstone. Pink to red oolites and crinoid fragments are common; locally the entire rock is tinted pink. The Levias is highly fossiliferous and contains the youngest occurrence of *Platycrinites penicillus*. Other

common fossils are fenestellid bryozoans, spiriferid and compositid brachiopods, and a variety of echinoderms.

The overlying Shetlerville Member is more silty and argillaceous than the Levias, and contains interbeds of gray, greenish gray, and reddish gray shale and claystone. The crinoid *Talarocrinus* is common. Thickness of the Shetlerville is 5 to 35 feet.

The Renault is 50 to 80 feet thick in southwestern Illinois and Missouri, and is not divided into members there. It is an interval of medium to dark gray, thin to medium bedded oolitic and fossiliferous limestone, intercalated with variegated shale and locally with calcareous sandstone. The lower contact is gradational and locally intertongues with the Aux Vases Sandstone.

Yankeetown Sandstone The Yankeetown is a unit of sandstone interbedded with siltstone and shale. The sandstone is light gray to reddish brown, very fine to fine grained, and thin to thick bedded. The shale is greenish gray, dark gray and reddish gray, silty, and partly calcareous. The Yankeetown is thick-

est in Missouri and adjacent parts of Illinois, where it is 45 to 80 feet thick. It gradually thins and becomes finer grained toward the southeast, intergrading with limestone and shale of the upper Renault and Downeys Bluff (fig. 4). The lower contact is locally conformable, slightly disconformable, or intertonguing.

Downeys Bluff Limestone The Downeys Bluff is ranked as a formation in some areas, but it is mapped as part of the Renault Limestone in Kentucky (fig. 2) and part of the Paint Creek Formation in southwestern Illinois and Missouri (fig. 4). It overlies the type Renault Limestone and should not be assigned to that formation. The Downeys Bluff is composed of light to dark gray and brownish gray, fine to coarse grained calcarenite. It is commonly crossbedded oolitic and crinoidal grainstone or packstone. Crinoid fragments replaced by pink to pale orange chert are diagnostic. In many places the Downeys Bluff contains nodules or lenses of gray to pink chert. Also present are interbeds of gray, greenish gray, and red, sandy, calcareous shale, some of which may be tongues of the Yankeetown Sand-

stone. The Downeys Bluff is 25 to 45 feet thick in southeastern Illinois and adjacent parts of Kentucky; westward it thins to fewer than 10 feet and is discontinuous. The lower contact is conformable and locally intertonguing.

Cedar Bluff Limestone The former Cedar Bluff Group (Swann 1963, p. 46-47) is herein reduced in rank to the Cedar Bluff Limestone (formation). The Cedar Bluff Group was a unit comprising the Renault Limestone, Yankeetown Formation, and Downeys Bluff Limestone in eastern and southeastern Illinois. The name Cedar Bluff was introduced by Swann (1963) to replace incorrect usage of "Renault" for a unit in the subsurface. In the area where the Cedar Bluff is recognized, the Yankeetown Sandstone changes facies to shale and intertongues with adjacent limestones (fig. 4). Not only is the Yankeetown unmappable in this area, but it is also the incorrect name to use for both a sandstone and a unit of shale and limestone. Where the Yankeetown is absent, the Renault and Downeys Bluff are difficult to distinguish. Use of the name Cedar Bluff Limestone is restricted

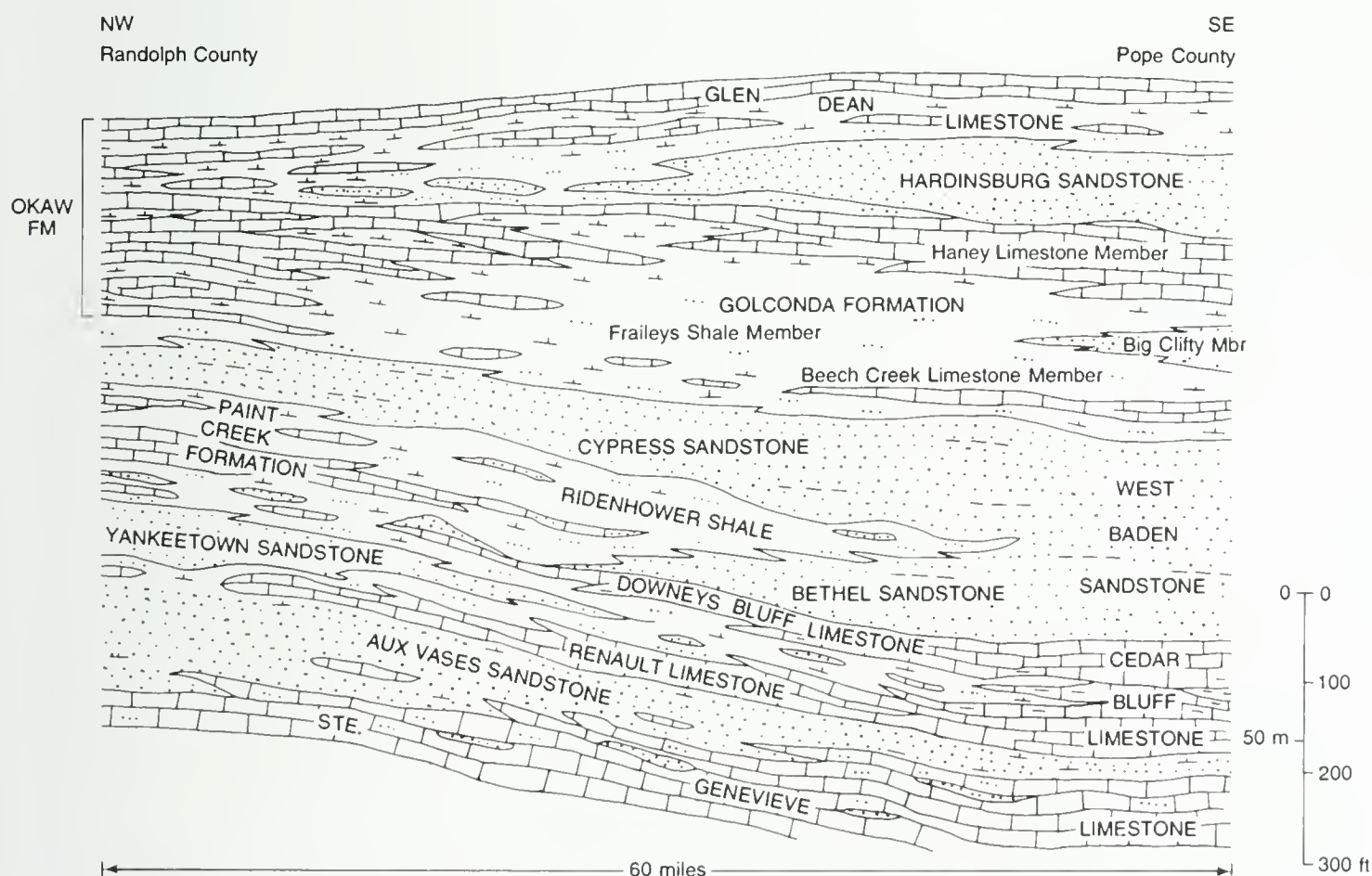


Figure 4 Facies and nomenclature changes in the lower part of the Pope Group, southern Illinois.

in this report to areas where the Yankeetown Sandstone is absent. The name Paoli Limestone, which has priority over Cedar Bluff, is used in Indiana for essentially the same interval of strata.

Bethel Sandstone The Bethel is a prominent sandstone in western Kentucky and southeastern Illinois, but it thins rapidly westward and occurs only as thin lenses in the western half of the Paducah Quadrangle (fig. 4). Where it is thick, the Bethel is a white to light gray, fine to medium grained quartzose sandstone. Locally it contains quartz granules; no other sandstone of the Pope Group is as coarse. The bedding varies from planar and ripple laminated to crossbedded to massive. In most of the study area, the lower contact of the Bethel is disconformable, and a basal conglomerate is commonly present (Weller and Sutton 1940, Baxter et al. 1967). I personally observed conformable relationships and intertonguing of lithologies at the Bethel-Cedar Bluff contact near the western limit of continuous Bethel Sandstone in Johnson County, Illinois. Maximum thickness of the Bethel is about 110 feet in parts of Pope and Hardin Counties, Illinois. It thins to fewer than 10 feet in Johnson County and is sporadically present farther west. Red claystone commonly occurs at the position of the Bethel in western Illinois.

Ridenhower Shale or Formation The Ridenhower is a unit of shale, or interbedded shale and limestone that overlies and grades laterally into the Bethel Sandstone. Close to the area of thick Bethel Sandstone in southern Illinois, the Ridenhower consists of dark gray and greenish gray, silty shale and siltstone to very fine sandstone that is crosslaminated and ripple laminated. Thin beds of dark gray to brown, very argillaceous and sandy limestone are present. The limestones and, less commonly, the clastic rocks contain marine fossils. Westward the shales become less sandy and the limestone beds increase in number and thickness. In southwestern Illinois, the Ridenhower shales are dark gray, greenish gray, and reddish gray, mottled, fissile, noncalcareous silty shales and clay shales. Limestones are mostly light to medium

gray, fossil-fragmental rocks that exhibit a wide variety of textures.

The Ridenhower is 30 to 40 feet thick in southwestern Illinois and as thick as 100 feet in parts of southeastern Illinois. It is absent in Pope and Hardin Counties along the southwest-trending belt where the Bethel and overlying Cypress Sandstones merge and are lumped as the West Baden Sandstone (fig. 4). In Kentucky southeast of the West Baden clastic belt, the Ridenhower reappears, but it is called the "Paint Creek" Formation by geologists in Kentucky.

Paint Creek Formation The Paint Creek Formation was originally defined in Randolph County, Illinois, by S. Weller (1913). Early mappers extended the Paint Creek through southern Illinois into western Kentucky, where "Paint Creek" is still used as a synonym for Ridenhower Formation. The type Paint Creek contains equivalents of the Ridenhower, Bethel Sandstone, and Downeys Bluff Limestone (fig. 4). Swann (1963) elevated the Paint Creek to a group and attempted to restrict its usage to western Illinois. In that area, however, the Bethel Sandstone changes facies to thin red mudstone, and the Downeys Bluff becomes thin and lenticular. The Ridenhower, Bethel, and Downeys Bluff are not mappable formations in the Paint Creek type area.

The Paint Creek is hereby revised back to a formation and restricted to its original type area of southwestern Illinois and the adjacent part of Missouri. The name Paint Creek should not be used in areas where the Bethel and Downeys Bluff are mappable as formations. The "Paint Creek" in western Kentucky should be renamed. These strata are equivalent to only the upper part of the type Paint Creek and differ substantially in lithology. The type Paint Creek and Kentucky "Paint Creek" are on opposite sides of the West Baden clastic belt.

As described in the northwestern portion of the study area, the Paint Creek contains largely limestone at the top and bottom and shale in the middle. The limestone is light to medium gray, pink, and purplish gray, and largely fine to coarse grained, oolitic and crinoidal grainstone. Shale in the Paint Creek is

partly calcareous and variegated in red, purple, ochre, and gray. Thickness increases southeastward from 35 to 60 feet in the Belgique and Lithium Quadrangles, Missouri, to as much as 150 feet in the Altenburg Quadrangle. The Paint Creek is 80 to 110 feet thick in western Jackson and Union Counties, Illinois.

Cypress Sandstone or Formation The Cypress Sandstone or Formation extends throughout the area of Pope Group outcrops in the Paducah Quadrangle, except in Missouri. Sandstone of the Cypress is generally very light to light gray, very fine to medium grained, and composed dominantly of quartz grains. In most of the study area, the lower part of the Cypress is coarser grained and thick bedded to massive, and contains few or no shale interbeds. The upper Cypress becomes finer grained and thin bedded to laminated and shaley. Gray, greenish gray, and reddish gray silty shale and siltstone are present in the upper Cypress. Carbonaceous shale and shaley coal occur in the middle to upper portion of the Cypress in Hardin County, Illinois, and southern Crittenden and eastern Livingston Counties, Kentucky. A 4-foot coal bed in the Cypress in the Fredonia Quadrangle (Rogers and Hays 1967) is the thickest coal reported anywhere in the Pope Group.

Where the Cypress Formation is thick, the lower contact typically is sharp and disconformable. Westward, however, the Cypress Formation grades laterally and intertongues with fine grained clastics of the Ridenhower and Paint Creek Formations (fig. 4). In most of southern Illinois and Kentucky, the Cypress is 65 to 130 feet thick. It gradually thins toward the northwest and is locally replaced by shale in Jackson County, Illinois. In the outcrops in the Missouri part of the Paducah Quadrangle, the Cypress consists of 10 to 20 feet of gray, greenish gray, and red shale and claystone.

West Baden Sandstone The Cypress and Bethel Sandstones are merged into a single unit in parts of Hardin and Pope Counties, Illinois. This unit, dominated by sandstone, is part of a southwest-trending clastic belt that was mapped in the sub-

surface to its northeastern outcrop in Indiana (Sullivan 1972). On either side of the clastic belt, the Cypress and Bethel are separated by wedges of shale and limestone. These fine grained strata, called Ridenhower in Illinois and Paint Creek in Kentucky, grade laterally and intertongue with the sandstones of the clastic belt.

The name West Baden Group was used by Gray et al. (1960) and Swann (1963) to designate the rocks of the clastic belt. Within this belt, however, the Cypress and Bethel Sandstones lose their identity, so the West Baden in effect becomes a formation (fig. 4). Sullivan (1972) used the name West Baden Group for the entire package of sandstone, shale, and limestone between the top of the Cypress and the base of the Bethel. Such usage may be handy for subsurface studies, but it obscures the facies relationship between the stacked sandstones and their laterally equivalent shales and limestones.

The West Baden Group is hereby reduced in rank to a formation, West Baden Sandstone, and restricted to the clastic belt where Cypress and Bethel are not differentiated.

Golconda Formation The Golconda Formation was named by Butts (1917) for Golconda, Pope County, Illinois. McFarlan et al. (1955) elevated the Golconda to a group and the constituent Beech Creek Limestone, Fraileys Shale, Big Clifty Sandstone, and Haney Limestone to formations. This revision was made in an off-handed manner, and no arguments were presented for the change in rank. McFarlan et al.'s revision in rank of the Golconda was accepted by the Illinois State Geological Survey but not by the Missouri, Kentucky, or U.S. Geological Surveys. Referring to the western Kentucky fluorspar district, Trace and Amos (1984, p. 14) wrote, "Exposures in the district are rarely complete enough to permit consistent subdivision into mappable units, although, at places, the Beech Creek and Haney are recognizable." The Golconda was not subdivided on any of the 7.5-minute geologic quadrangle maps in the Paducah Quadrangle. Thus, the Beech Creek, Fraileys, Big Clifty, and Haney do not meet the requirement of mappability specified for a valid formation

in the North American Stratigraphic Code (1983, Article 24). These units are hereby reduced in rank to members and the Golconda to a formation throughout the Paducah Quadrangle.

The basal *Beech Creek Limestone Member* is a widely traceable subsurface marker, commonly called the "Barlow lime." On the outcrop, it is less than 10 feet thick and probably discontinuous. In western Kentucky, the Beech Creek is brownish gray, medium grained, partly oolitic limestone that commonly displays cross-bedding and ripple marks. The Beech Creek in Illinois was described by Swann (1963, p. 35) as being a pelletal or "pseudo-oolitic" limestone that is darker than other adjacent limestone beds. He also noted that large brachiopods, including *Productus inflatus*, are common near the top of the Beech Creek, and small gastropods, small pelecypods, and foraminifera are more abundant near the base.

The *Fraileys Shale Member* is 40 to 100 feet thick in the Paducah Quadrangle and consists of shale containing thin limestone interbeds. To the west, the Fraileys is thinner and the shale is dark gray, calcareous, and free of silt. Eastward, the Fraileys is commonly divisible into a lower unit of dark gray, fissile, sideritic shale and an upper unit of gray calcareous shale intercalated with argillaceous, highly fossiliferous limestone. Siltstone in the middle Fraileys is a distal facies of the Big Clifty Sandstone Member (fig. 4). A unit of red and green variegated mudstone occurs widely near the top of the Fraileys.

The *Big Clifty Sandstone Member* is confined mostly to the area east of the Paducah Quadrangle. The sandstone grades westward to the Fraileys Shale (fig. 4). Near the east edge of the study area in Kentucky, the Big Clifty reaches a thickness of about 25 feet. It is described as light gray to greenish gray, very fine to fine grained, calcareous, micaceous, and thinly bedded.

The Haney Limestone Member at the top of the Golconda is predominantly limestone containing interbeds of shale. The limestone is light to dark brownish gray, fine to coarse grained, and fossiliferous. A wide range of carbonate textures is present, but skeletal packstone is most

commonly encountered (Vincent 1975, Treworgy 1988). Echinoderms and bryozoans are the principal skeletal components. Oolitic grainstone is common near the top of the Haney. Beds of skeletal wackestone, lime mudstone, and buff-weathering microcrystalline dolomite occur at various positions in the member. Shale interbeds are gray to greenish gray and calcareous. The lower contact of the Haney is sharp to gradational and probably intertongues with the Fraileys in places. Thickness of the Haney ranges from 15 to 120 feet, with much local variation.

Total thickness of the Golconda increases from 85 feet in Missouri to 100 to 120 feet in southwestern Illinois and 120 to 180 feet in southeastern Illinois and Kentucky. The lower contact is conformable and is sharp in some areas, gradational in others.

Hardinsburg Sandstone or Formation The Hardinsburg Sandstone or Formation is lithologically similar to the Cypress. Light gray quartzose sandstone, very fine to fine grained (rarely medium grained) and laminated to massive, is the dominant lithology. This sandstone is interbedded with medium to dark gray and greenish gray, well laminated clay shale, silty shale, and siltstone. The thickest and coarsest sandstone bodies are mostly in the lower part of the Hardinsburg. Shaley coal beds as thick as 2 feet, overlying rooted claystones and overlain by shales containing plant fossils, occur in the middle part of the Hardinsburg in Crittenden and Livingston Counties, Kentucky. Thinner coals and rooted zones are found in the middle to upper Hardinsburg in southeastern Illinois.

The Hardinsburg is as thick as 180 feet in southern Pope County, Illinois, and 150 feet in portions of Crittenden County, Kentucky. The area of thickest Hardinsburg nearly coincides with the underlying West Baden clastic belt. The Hardinsburg thins westward across southern Illinois, and grades to dark gray shale containing sandstone laminae. Northwest of Union County, Illinois, the Hardinsburg is less than 20 feet thick and cannot be reliably distinguished from adjacent shales. The lower contact is disconformable in many places where the sandstone is thick; elsewhere it is gradational.

Glen Dean Limestone The Glen Dean is a unit of limestone and shale that is recognized throughout the study area (except where eroded). The upper part of the Glen Dean is predominantly limestone, whereas middle and lower parts contain variable proportions of limestone and shale. As in the Golconda Formation, limestone in the Glen Dean is light to dark gray and brownish gray and fine to coarse grained. Much of it is crinoid-bryozoan packstone and grainstone; oolitic grainstone is common at the top. Shale in the Glen Dean is greenish to olive gray and dark gray and mostly mottled, soft, fissile, and calcareous. Laminae, lenses, and interbeds of limestone are common in the shales. Siltstone and lenticular sandstone occur in the lower Glen Dean near the southeastern corner of the quadrangle.

The Glen Dean is 40 to 110 feet thick in the study area, averaging about 70 feet. The lower contact is conformable and commonly gradational.

Okaw Formation The Okaw Limestone was named by S. Weller (1913) for exposures along the Okaw (Kaskaskia) River in Randolph County, Illinois. Swann (1963) revised the rank of the unit to Okaw Group, which he defined as containing the Beech Creek Limestone, Fraileys Shale, Haney Limestone, Hardinsburg Formation, and Glen Dean Limestone. In the area of southwestern Illinois where the name Okaw is used, the Hardinsburg is thin and discontinuous and cannot be mapped as a distinct formation. Also, limestones of the Glen Dean and Golconda (Haney and Beech Creek) in this area are similar in lithology, preventing distinction of the formations. The Okaw Group is, therefore, revised back to Okaw Formation in this report, and its usage is restricted to areas of southwestern Illinois where the Golconda, Hardinsburg, and Glen Dean cannot be mapped separately. The top of the Glen Dean or Okaw is the top of the lower part of the Pope Group, as shown on the map.

Tar Springs Formation The Tar Springs is present throughout the outcrop belt, but its lithologic content varies from entirely sandstone to entirely shale. The sandstone is

light gray to medium brownish gray, very fine to fine grained, and composed dominantly of quartz. It is commonly silty and slightly micaceous. Bedding ranges from laminated to massive; crossbedding, ripple marks, and trace fossils are common. Locally the sandstone is calcareous and contains molds of marine fossils. Siltstone, silty shale, and clay shale in the Tar Springs are medium to dark gray and greenish gray. These rocks commonly are interlaminated with sandstone and display planar, ripple, and slumped laminations. Thin coal and rooted claystone are common in the upper half of the Tar Springs. As many as three coal beds may occur in a single section. The most widely present coal is at the top of the formation.

Thickness of the Tar Springs is 20 to 145 feet in the study area. The maximum thickness is in Hardin County, Illinois. The formation averages about 100 feet thick in Kentucky and southeastern Illinois, and generally thins westward; but substantial local variation is evident. As with other clastic formations of the Pope Group, the nature of the lower contact of the Tar Springs differs from one place to another. In some areas the contact is erosional on the Glen Dean Limestone, but in other areas gradation and intertonguing have been observed between Tar Springs and Glen Dean (Nelson 1993).

Vienna Limestone The Vienna is a thin but widespread and distinctive unit in the Paducah Quadrangle. In most places the Vienna is composed entirely of limestone, but locally two or more limestone beds alternate with shale. Characteristically, the limestone is dark gray and brownish gray, dense and micritic (lime mudstone and skeletal wackestone), and very siliceous. Bands and lenses of chert are abundant throughout. The Vienna contains a greater proportion of chert than any other limestone of the Pope Group. The limestone weathers to a distinctive residuum of brown tripolitic material that resembles porous sandstone, intermixed with angular blocks of bleached chert containing molds of crinoids, bryozoans, and brachiopods. Light gray, coarse grained, crinoidal grainstone occurs in the upper part of the Vienna in

some areas. Shale in the Vienna is dark olive gray to black, fissile, and calcareous. It occurs mostly in the upper part of the unit.

As a single limestone bed, the Vienna is 7 to 40 feet thick. It is thinnest in the northwestern part of the study area and thickest in its type area of Johnson County, Illinois. In a few places the Vienna contains interbedded shale and limestone as thick as 60 feet. The lower contact typically is sharp yet conformable.

Waltersburg Sandstone or Formation The Waltersburg is well developed in the eastern half of the Paducah Quadrangle; westward it becomes thin, dominated by shale, and difficult to map. In the type area of southeastern Johnson County, Illinois, the Waltersburg is composed of bluff-forming, crossbedded sandstone that is up to 85 feet thick and underlain by 10 to 40 feet of poorly exposed, dark gray laminated shale. Elsewhere in southeastern Illinois and Kentucky, the Waltersburg generally is a unit of 25 to 100 feet of interlaminated shale, siltstone, and very fine sandstone. These rocks are greenish gray to dark gray and show planar and ripple laminations. Siltstone that weathers to reddish brown and black rhombohedral fragments is common in Kentucky. Thin coal beds and shale containing plant fossils occur locally. West of Johnson County the Waltersburg is reduced to 10 to 30 feet of dark colored, laminated clay shale and silty shale that contains lenses of very fine argillaceous sandstone. In parts of southwestern Illinois, the Menard, Waltersburg, and Vienna Formations cannot be mapped separately.

The lower contact of the Waltersburg appears to be conformable and is gradational to sharp.

Menard Limestone The Menard Limestone is present throughout the outcrop belt in the Paducah Quadrangle, and it extends northward into the subsurface. Limestone and minor dolomite that have numerous thin interbeds of shale typify the Menard.

Limestone of the Menard is dominantly medium to dark gray and brownish gray and micritic (lime mudstone and skeletal and pelletal wackestone). Beds of dense, sublitographic, laminated to massive

lime mudstone are common in the lower part of the Menard. This limestone weathers to smooth light gray surfaces. Some layers are dolomitic and weather orange brown. Whole fossils are common, particularly the brachiopods *Spirifer increbescens* and *Composita subquadrata*. The upper part of the Menard contains more fossil-fragmental limestone, but fewer whole fossils. This limestone is commonly siliceous and weathers to mottled gray, rough-textured surfaces. Light colored crinoidal and oolitic grainstone occurs locally in the upper Menard. Throughout the Menard, the limestone occurs in hummocky beds a few inches to 2 feet thick, separated by argillaceous partings. Intervals of limestone 5 to 40 feet thick alternate with intervals of shale 1 to 20 feet thick. Shale in the Menard is medium to dark gray, olive gray, and greenish gray; soft, clayey, and blocky to fissile; and commonly calcareous and highly fossiliferous.

Swann (1963) divided the Menard into five members: Walche Limestone (basal), unnamed shale, Scottsburg Limestone, unnamed shale, and Allard Limestone (at the top). Only a few mappers have identified these members in outcrops, but typically poor exposures hinder recognition of members. Some individual beds in the Menard, however, are widely traceable in the subsurface.

The Menard Limestone thickens regionally southward across the Paducah Quadrangle from 70 to 140 feet. Thickness varies gradually. The lower contact is conformable and sharp to slightly gradational.

Palestine Sandstone or Formation The Palestine is composed of sandstone, siltstone, shale, and minor claystone and coal. The sandstone is light gray or light to medium brownish gray and very fine grained; it is less commonly fine grained. In most of the study area, the sandstone is laminated or thinly bedded and argillaceous to silty. It contains much fine grained mica and carbonaceous material. Trace fossils, especially large curving trails, are abundant in sandstone of the Palestine in the western part of the quadrangle. Intervals of clean crossbedded sandstone are more common to the east. Shale and siltstone of the Palestine are medium to

dark gray and commonly interlaminated with sandstone. Dusky red and green variegated claystone occurs near the top of the Palestine in western Kentucky. Thin coal was observed near the top of the formation of several localities.

The Palestine Formation is 40 to 80 feet thick in most of the report area, but it attains a thickness of 120 feet in small areas to the northeast. Local thickness varies moderately. Although the lower contact is disconformable in a few places, it is typically conformable and gradational.

Clore Formation The Clore Formation is a complex unit that contains shale, limestone, siltstone, and sandstone in roughly that order of abundance. Swann (1963) divided the Clore into three members that can be recognized in most areas of the Paducah Quadrangle.

The *Cora Member*, at the base of the Clore Formation, is 30 to 75 feet thick and composed of shale and thin limestone interbeds. Shale in the Cora is dark gray to dark olive gray and greenish gray, blocky to fissile, and partly calcareous. Siltstone is locally present, but most of the shale lacks silt. Limestone occurs as lenses and beds a few inches thick in the lower part of the Cora and as beds 1 to 5 feet thick in the upper Cora. Most of it is dark gray argillaceous lime mudstone that breaks into small platy fragments when struck. The Cora is fossiliferous; among the most abundant fossils are *Cliothyridina sublamellosa*, *Batostomella nitidula*, *Composita*, *Spirifer* and other brachiopods, and bryozoans.

The middle *Tygett Sandstone Member* of the Clore is absent or up to 70 feet thick; it is thickest in eastern Johnson and western Pope Counties, Illinois. As many as three sandstone intervals separated by thin limestones are present in this area of Johnson and Pope Counties. Clastic intervals in the Tygett commonly coarsen upward from dark gray silty shale at the base, through siltstone to fine grained, thin bedded sandstone at the top. Trace fossils are common; root casts and thin coals occur at the tops of the sandstones. Limestone in the Tygett Member is lithologically similar to limestone in the Cora Member.

The *Ford Station Member* at the top of the Clore contains variable

proportions of shale and limestone. In southwestern Illinois, the lower Ford Station contains dolomitic, dark gray lime mudstone that weathers to olive gray with orange mottling. Green shale and claystone overlie the limestone in this part of Illinois. Eastward some of the limestone in the Ford Station is silty to sandy. Thickness of the member is 15 to 50 feet.

Total thickness of the Clore increases from 40 feet in Randolph County, Illinois, to 150 feet in Johnson County. The unit is 80 to 110 feet thick in most of the southeastern Illinois and western Kentucky.

Degonia Sandstone or Formation The Degonia Sandstone is well developed in the northwestern part of the Paducah Quadrangle, and becomes thin and dominated by shale toward the southeast. In the northwest, the Degonia is 60 to 125 feet thick, and the principal lithology is sandstone that is white to light yellowish gray, very fine to fine grained, well sorted, and quartzose. It varies from ripple laminated to crossbedded to nearly massive. Interbedded with the sandstone are gray ripple-laminated siltstone and silty shale. In southeastern Illinois the Degonia Formation is 15 to 40 feet thick and mostly composed of shale and siltstone. These rocks are dark gray, greenish gray, and olive gray and laminated to thinly bedded. Ripple marks and trace fossils are common. White to brown chert (silicified siltstone?) occurs in beds up to several feet thick near the base and, locally, in the upper part of the Degonia. An interval of red and green variegated claystone occurs at the top of the Degonia throughout the study area. The lower contact is conformable to the southeast and locally disconformable to the northwest.

Kinkaid Limestone The youngest formation in the Pope Group, the Kinkaid Limestone, is divisible into four members in the Paducah Quadrangle. These are the Negli Creek Limestone Member at the base, the Cave Hill Member, the Goreville Limestone Member, and the Grove Church Shale Member. The Grove Church, proposed as a separate formation by Swann (1963), was revised to a member of the Kinkaid by Nelson et al. (1991).

vised to a member of the Kinkaid by Nelson et al. (1991).

Maximum recorded thickness of the Kinkaid is 230 feet, in Johnson County, Illinois. Everywhere else the Kinkaid is thinner because of post-Mississippian erosion. In some places the Kinkaid is completely eroded, and Pennsylvanian rocks lie on older formations. Where not eroded, however, members of the Kinkaid are remarkably uniform in thickness and lithology.

The basal *Negli Creek Limestone Member* is 25 to 35 feet thick and composed dominantly of medium to dark brownish gray, slightly argillaceous, micritic limestone. It is commonly siliceous and contains chert lenses. Most of the limestone is lime mudstone and wackestone, but light-colored crossbedded skeletal and oolitic packstone and grainstone occur in the upper Negli Creek in places. Limestone beds are a few inches to about 2 feet thick and they are separated by wavy dark shale partings. Large bellerophonid gastropods, *Girvanella* oncoids, and the demosponge *Chaetetes*, when found together, are diagnostic for the lower Negli Creek.

The *Cave Hill Shale Member* is 70 to 100 feet thick and divisible into three units. At the base is 7 to 45 feet of greenish gray and dark gray shale that thickens northeastward and coarsens upward to siltstone toward the northeast. Above this is 30 to 75 feet of intercalated limestone and shale; the proportion of shale increases toward the northeast. Limestone of the middle part of the Cave Hill varies in color and texture, but slightly dolomitic fossiliferous lime mudstone is most typical. This limestone, dark gray when fresh, weathers to smooth light gray surfaces and breaks with conchoidal fracture. Bands and nodules of dark gray chert are abundant. At the top of the Cave Hill is 10 to 15 feet of variegated green and red claystone that contains lenses and thin beds of fossiliferous limestone and dolomite.

The *Goreville Limestone Member* is dominantly a light gray, coarse grained crinoidal grainstone in the western part of the study area. Eastward, it tends to become darker and more micritic and argillaceous and to have laminae and thin interbeds of dark gray shale. Characteristic fossils are teeth of shell-crusher sharks

and very large specimens of *Archimedes*.

The *Grove Church Shale Member* has a maximum known thickness of 74 feet in a borehole in northern Johnson County, Illinois. This member occurs as poorly exposed, scattered erosional remnants beneath the sub-Pennsylvanian unconformity. Mottled olive to greenish gray, well laminated clay shale is the most common lithology. Portions of the shale are calcareous, and lenses and thin beds of highly fossiliferous limestone are present. Red and green shale, silty shale and siltstone, and carbonaceous shale containing plant fossils also have been reported. In wells where the thickest sections of Grove Church are preserved, the uppermost portion is dominantly limestone. This youngest Mississippian limestone in the Illinois Basin does not crop out.

PENNSYLVANIAN SYSTEM

Rocks of the Pennsylvanian System unconformably overlie the Pope Group in the Paducah Quadrangle. Paleovalleys several hundred feet deep were eroded into Mississippian strata prior to Pennsylvanian sedimentation (Bristol and Howard 1971). In a few areas, Mississippian strata were also tilted slightly by tectonic forces before the onset of Pennsylvanian sedimentation. Pennsylvanian rocks overlie Mississippian formations ranging from the Menard Limestone through the Kinkaid Limestone in the Paducah Quadrangle.

Pennsylvanian lithostratigraphic classification is currently in a state of flux. An agreement to standardize Pennsylvanian formations in Indiana, Illinois, and Kentucky has been proposed but not finalized. Within the Paducah Quadrangle, four mapping units can be recognized: Caseyville Formation (oldest), Tradewater Formation, Carbondale Formation, and McLeansboro Group. In addition to these units, the croplines of several coal beds are shown on the geologic map (plate 1).

Caseyville Formation The Caseyville Formation crops out in grabens in the Illinois-Kentucky fluorspar district, around the rim of the Eagle Valley-Moorman Syncline, and in a belt that curves northwestward from Pope to Jackson Counties,

Illinois. In northwestern Jackson and Randolph Counties, the Caseyville and the overlying Tradewater Formation have not been distinguished and are mapped as a single unit (plate 1).

The Caseyville Formation is characterized by bluff-forming quartzose sandstone (orthoquartzite or quartz arenite) that contains numerous well rounded white quartz pebbles. These sandstones are coarser than any in the Pope Group and are mineralogically more mature than younger Pennsylvanian sandstones. The Caseyville also contains fine grained sandstone and light to dark gray laminated siltstones and shales identical to Pope Group and post-Caseyville lithologies. Differentiation of the Caseyville thus can be problematic where it is in fault or depositional contact to these other units. The Caseyville also contains lenticular shaley coals less than 2 feet thick, which commonly overlie claystones or coals that contain fossilized root casts. Argillaceous to sandy limestone is a rare lithology in the Caseyville.

The Caseyville is sparsely fossiliferous. Plant fossils occur as compressions in shale and as casts in sandstone. Marine fossils have been described from the basal (Jennings and Fraunfelter 1986) and middle Caseyville (Baxter et al. 1963, Devera et al. 1987). Trace fossils have been observed in numerous outcrops of the Caseyville.

Four members of the Caseyville are recognized in southeastern Illinois and parts of western Kentucky. From oldest to youngest they are the Wayside Member (called Lusk Shale in some older reports), Battery Rock Sandstone Member, an unnamed member (formerly called Drury Member), and Pounds Sandstone Member. The Battery Rock and Pounds are cliff-forming conglomeratic sandstones. The Wayside and unnamed members are dominantly fine grained, thin bedded sandstone, siltstone, and shale. Lenticular rock bodies and rapid lateral variation characterize the Caseyville in outcrops and subsurface.

Thickness variations of the Caseyville are abrupt, due in part to deposition on an irregular surface. Inconsistent placement of the upper contact also is a problem in some areas. Where it is questionable, the contact

and southeastern Illinois, the Caseyville is 190 to 500 feet thick. It thins to 200–300 feet westward in Union County, Illinois, and probably pinches out northwestward in Randolph County (Willman et al. 1967, Sonnefield 1981).

Tradewater Formation The Tradewater Formation, a succession of interbedded sandstone, siltstone, shale, and minor coal and limestone, was originally described in western Kentucky. The Tradewater in Illinois formerly was divided into the Abbott (older) and Spoon Formations by Kosanke et al. (1960). The Abbott and Spoon, however, proved to be unmappable in many areas; therefore, the names were abandoned and Tradewater was reinstated (Jacobson 1991).

Lithologically the biggest distinction between Tradewater and Caseyville Formations is in the character of the sandstones. Those of the Caseyville are clean, often conglomeratic quartz arenites, whereas those of the Tradewater are lithic arenites that rarely contain quartz pebbles. Tradewater sandstones contain much mica, feldspar, lithic material, and interstitial clay. The change in the two sandstones is transitional; lower Tradewater sandstones closely resemble Caseyville sandstones. Siltstone and shale of the Tradewater and Caseyville generally are indistinguishable. However, the Tradewater, particularly the upper part, generally contains a greater proportion of fine grained clastics than the Caseyville. Coal beds are numerous but lenticular. Thin units of argillaceous marine limestone and fossiliferous shale occur in the upper part of the Tradewater.

The lower contact of the Tradewater is transitional to the Caseyville. Most mappers drew this contact at the uppermost occurrence of pebbly quartzose sandstone. In places, sandstone mapped as Caseyville probably is in facies relationship with shale mapped as Tradewater. Dashed lines on the geologic map indicate questionable placement of the contact. The Tradewater and Caseyville have not been differentiated in northern Jackson and Randolph Counties, Illinois.

The top of the Tradewater is mapped at the base of the Davis Coal Member of the Carbondale For-

mation in Kentucky and southeastern Illinois (plate 1). The Davis Coal becomes discontinuous and is not mapped west of longitude 89° W. West of this line, the upper boundary of the Tradewater steps upward about 50 feet to the base of the Colchester Coal (plate 1, fig. 5).

The outcrop of the Murphysboro Coal Member is shown on the geologic map in Jackson and western Williamson County, Illinois (plate 1). The Murphysboro Coal, in the upper part of the Tradewater Formation, reaches a thickness of 7 feet and has been mined extensively.

The Tradewater Formation thickens eastward from about 300 feet in Jackson County to roughly 700 feet near the east edge of the study area.

Carbondale Formation The Carbondale Formation was named for Carbondale, Illinois, by Shaw and Savage (1912), who chose the Murphysboro and Herrin Coals as its bounding members. Since then, the limits of the Carbondale have been revised many times by various geologists working in different areas of the basin. A full account of the revisions would cover many pages, and is not presented in this report. In compiling the bedrock geologic map, I selected boundaries of the Carbondale Formation at coal seams that have been mapped most widely and that correspond closely with traditional boundaries of the Carbondale. The base of the Carbondale is

mapped at the base of the Davis Coal east of longitude 89° W (plate 1), and steps upward about 50 feet to the base of the Colchester Coal west of longitude 89° W (plate 1, fig. 5). The top of the Carbondale is at the top of the Herrin Coal throughout the study area. This definition of the Carbondale Formation should be considered *ad hoc*, not a formal redefinition.

Sandstone, siltstone, shale, coal, and limestone constitute the Carbondale Formation. Siliciclastic rocks account for at least 90% of the volume of the formation. These rocks do not differ appreciably in composition from clastic rocks in the upper part of the Tradewater Formation. The chief distinction between the Carbondale and the Tradewater is that coals and limestones are thicker, more numerous and more persistent in the Carbondale. Several coals and limestones of the Carbondale extend across the entire Paducah Quadrangle (and much farther), whereas Tradewater coals and limestones are markedly lenticular. Nearly all of the mining activity and remaining coal resources of the Illinois Basin are in the Carbondale Formation.

Another noteworthy feature of the Carbondale Formation is its cyclicity, or vertical recurrence of lithologic sequence. A typical cycle includes coal (base), thin black fissile shale, marine limestone, gray shale grading upward to sandstone, non-marine limestone, rooted claystone, and coal (top). Many variations on

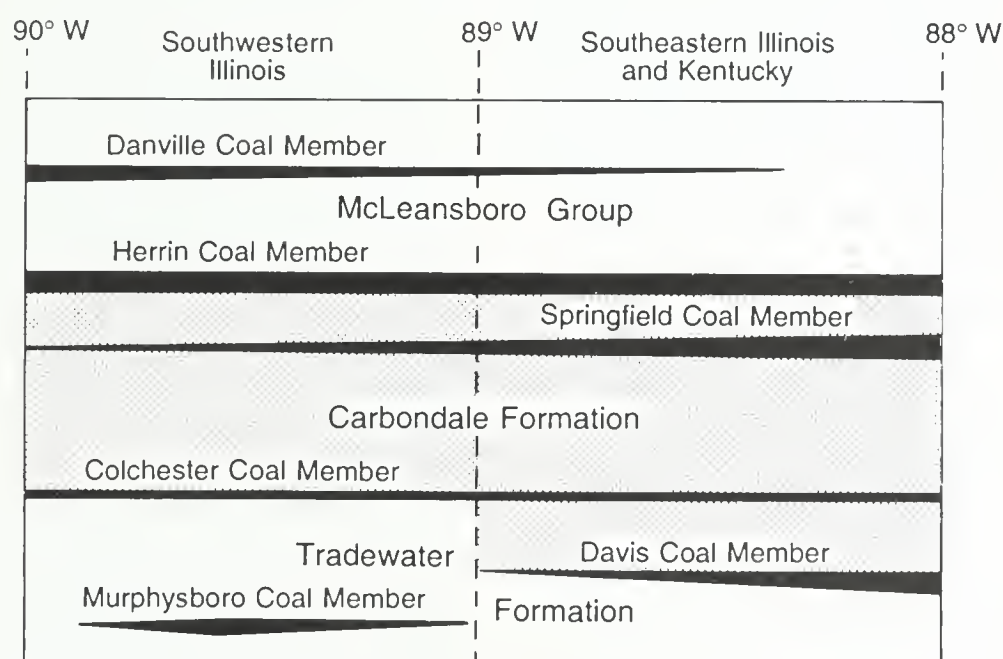


Figure 5 The Carbondale Formation (shaded interval), as defined in this report, with reference to major coal members. Not to scale.

this sequence are evident. Sedimentary cycles in the Carbondale Formation were first described near Peoria, Illinois, by J.A. Udden in 1912, and later developed into the "cyclothems" of H.R. Wanless, J.M. Weller, R.C. Moore, and others from the 1930s onward.

The outcrops of the Davis (oldest), Colchester, Springfield, and Herrin Coal Members of the Carbondale Formation appear on the geologic map (plate 1).

The Carbondale Formation gradually thickens eastward across the Paducah Quadrangle from about 175 to 400 feet.

McLeansboro Group The McLeansboro Formation was originally defined by DeWolf (1910). Kosanke et al. (1960) elevated the McLeansboro to a group and named three formations therein. Because no accurate map exists showing the limits of these formations in the Paducah Quadrangle, the McLeansboro is shown as a single unit on plate 1. The McLeansboro is identical to the Sturgis Formation, which was proposed during the mapping program in western Kentucky (Kehn 1973). The name Sturgis Formation is hereby suppressed on the basis of priority, and the name McLeansboro Group is extended throughout the Paducah Quadrangle.

The McLeansboro Group underlies a large area in the northeastern part of the Paducah 1° × 2° Quadrangle (plate 1). Its outcrop is largely concealed by glacial drift; the McLeansboro is known mainly from subsurface data, especially coal-test borings.

The McLeansboro resembles the Carbondale lithologically. Sandstone (lithic arenite), siltstone, and shale are the predominant lithologies. Limestones are generally thicker and more numerous, and coals are thinner (too thin to mine) in the McLeansboro than in the Carbondale. Details of the lithologic succession are illustrated on the stratigraphic columns that accompany the geologic map.

The upper boundary of the McLeansboro Group is the pre-Quaternary erosion surface throughout the study area and the Illinois Basin. About 900 feet of McLeansboro strata are preserved at the northeast corner of the quadrangle. The greatest known thickness, however, is in

a graben just east of the Ohio River in the Grove Center Quadrangle in Union County, Kentucky (Palmer 1976). A borehole in this area penetrated more than 2,100 feet of strata above the Carthage Limestone Member, which is about 500 feet above the Herrin Coal. Permian fusulinids were described about 1,650 feet above the Carthage in a drill core a few miles east of the Grove Center Quadrangle (Kehn et al. 1982). Thus, Permian beds probably also exist in the graben in the Grove Center Quadrangle.

CRETACEOUS SYSTEM

Weakly lithified sedimentary rocks of Late Cretaceous age occur in the Mississippi Embayment in the southern part of the Paducah Quadrangle. Cretaceous strata overlie Paleozoic rocks with an angular unconformity, and in turn are overlapped southward by Tertiary strata. All Cretaceous rocks are combined as a single unit on the geologic map (plate 1). One inconsistency was unavoidable. In Kentucky, the Clayton Formation, a thin unit of Paleocene age, was combined with Cretaceous strata on available source maps. In Illinois and Missouri, the Clayton has been mapped with the overlying Porters Creek Clay as part of the Midway Group.

The Cretaceous System thickens southward from a feather-edge to more than 450 feet in wells near Olmsted, Pulaski County, Illinois (Ross 1964, Kolata et al. 1981).

Little Bear Soil The Little Bear Soil is developed in the residuum on Paleozoic rocks beneath Cretaceous sediments. It is composed of yellow, brown, and red, silty clay that contains abundant chert fragments and brown to black limonitic nodules. The soil is sporadically developed and generally less than 10 feet thick, but locally it may be much thicker (Kolata et al. 1981). Exposures occur along the Union Pacific Railroad south of Thebes, Illinois.

Tuscaloosa Gravel or Formation The Tuscaloosa occurs in several outliers resting on Mississippian bedrock near the southeast corner of the Paducah Quadrangle (plate 1). It is also present in scattered outcrops and wells near the edge of the Mississippi Embayment in far-southern

Illinois. In most places the Tuscaloosa is composed of white to light gray chert gravel, commonly stained yellow to brown. Most pebbles are 1 to 3 inches in diameter, but occasional cobbles are as large as 10 inches. Pebbles are subrounded to subangular, except near the base of the Tuscaloosa, where some are angular. The gravel is dominantly chert with small amounts of other sedimentary rock fragments such as sandstone, most of which appear to be derived from Mississippian strata in the vicinity (Olive 1980, Trace and Amos 1984).

The gravel has a matrix of light gray clay, silt, and quartz sand. Cement is absent, except along some faults, where ferruginous cements are present. Bedding and other sedimentary structures are poorly developed. Lenses of sand, silt, and clay occur within the gravel; locally, the entire Tuscaloosa may be composed of sand. Reddish brown fine to medium grained sand and sandstone in the Eddyville Quadrangle (Kentucky) were mapped as Tuscaloosa by Rogers (1963).

Thickness of the Tuscaloosa is a few feet to 75 feet in most places. A maximum thickness of 180 feet was reported in the Calvert City Quadrangle (Amos and Finch 1968). The lower contact is either gradational to the Little Bear Soil or an angular unconformity on Paleozoic strata.

McNairy Formation The McNairy is the thickest and most widespread Cretaceous formation in the Paducah 1° × 2° Quadrangle. The largest area of outcrops is in the south-central part of the study area in Illinois and Kentucky (plate 1). Extensive areas of McNairy also occur in the Benton Hills and on Crowley's Ridge in Missouri (plate 1). North of these areas, the McNairy occurs as small outliers. The McNairy is mapped within grabens in Ordovician bedrock in the Dongola, Marble Hill, and Scopus Quadrangles, Missouri (plate 1).

The McNairy consists mainly of sand and weakly indurated sandstone intercalated with lesser amounts of clay, silt, gravel, and lignite. The sand is white to yellow, red and brown, and mostly fine to medium grained. Quartz is the major constituent, but mica is conspicuous and glauconite is common. Scattered

chert granules are present. Locally, the sandstone is strongly cemented by iron oxides. White, crossbedded quartz arenite ("Commerce quartzite"), composed of well rounded sand, occurs locally from the Thebes area northward to near Jonesboro, Illinois. Clay and silt in the McNairy are light to dark gray, micaceous, and lignitic. They occur as lenses in sand and, in parts of Illinois, as a unit called the Levings Member, which is up to 120 feet thick. Chert gravels occur locally near the base of the McNairy and can be difficult to distinguish from the Tuscaloosa. Lignite beds are lenticular and less than 1 foot thick. Petrified wood and silicified paleosols occur in the McNairy in Alexander County, Illinois, particularly in the Thebes Quadrangle.

The McNairy is up to 185 feet thick in Missouri (Oran Quadrangle). In Illinois, it reaches 450 feet in the subsurface. The undifferentiated McNairy and Clayton Formations have a maximum thickness of about 300 feet in western Kentucky (Olive 1966a and b). The McNairy overlies either the Tuscaloosa Gravel conformably or Paleozoic rocks unconformably.

Owl Creek Formation The Owl Creek Formation is identified at scattered localities in the Illinois and Missouri portions of the Paducah Quadrangle. It is a unit of micaceous and glauconitic clay and silt. Colors are yellow, brown, and greenish gray. Sand is scattered through the clay and occurs as laminae and lenses. Gastropods, pelecypods, cephalopods, and U-shaped burrows are common. The Owl Creek has a maximum thickness of about 20 feet and overlies the McNairy conformably or with a slight disconformity.

TERTIARY SYSTEM

Paleocene Series: Midway Group

The Midway Group comprises the Clayton Formation and the Porters Creek Clay, both of Paleocene age. The Midway Group has been mapped in Illinois and Missouri. The Clayton Formation was not separated from the McNairy Formation by mappers in Kentucky, but the Porters Creek Clay was mapped there. The Midway Group crops out in the Mississippi Embayment near the south border of the study area (plate 1).

Clayton Formation The Clayton is a thin but widespread unit of green to greenish brown or orange brown very glauconitic clay. It is micaceous and contains lenses of sand, mainly near the base. The clay is commonly bioturbated and contains bivalves, gastropods, and foraminifera. Thickness is 5 to 20 feet, and the lower contact is disconformable.

Porters Creek Clay The Porters Creek is a unit of greenish gray, olive gray, and locally black massive, blocky clay. It typically weathers light gray and exhibits conchoidal fracture. The clay is mostly calcium montmorillonite and is mined for use as absorbants. Silt, sand, mica and lignite flakes, and glauconite are common near the base. Fossils include gastropods, bivalves, radiolarians, palynomorphs, and fish remains. The Porters Creek is 45 to 220 feet thick; maximum thickness is in parts of Ballard and McCracken Counties, Kentucky. The contact to the Clayton is conformable.

Eocene Series

As shown on the geologic map, the Eocene Series comprises the undi-

vided Wilcox Sand and Claiborne Formation. These deposits are mostly concealed by alluvium along the south-central edge of the Paducah 1°× 2° Quadrangle (plate 1). Outliers have been mapped along Crowley's Ridge and in the Benton Hills, Missouri (plate 1).

Wilcox Sand The Wilcox consists of white to yellowish brown, loose to weakly indurated sand, with occasional lenses of clay and lignite. The sand is fine to very coarse grained and contains laminae and lenses of small quartz and chert pebbles. Sand-size grains of kaolinitic clay, called "sawdust sand," are characteristic of the Wilcox in some areas. Clay in the Wilcox is gray to reddish brown and partly silty. The Wilcox is absent or up to 125 feet thick in Missouri and as thick as 250 feet in Illinois and Kentucky. The lower contact is disconformable.

Claiborne Formation The Claiborne occurs only in Ballard County, westernmost Kentucky, where it was combined with the Wilcox in mapping. The Claiborne is mostly sand interbedded with silt and clay. Sand is white, yellow, red and brown, very fine to very coarse, angular to subrounded, and crossbedded. Clay pebbles or rip-up clasts are common. Clay and silt in the Claiborne are light gray to brown, sandy, and kaolinitic. Maximum thickness of the Claiborne is 180 feet in the La Center Quadrangle. The lower contact is disconformable; the Claiborne fills channels eroded into the Wilcox. The Claiborne is overlain unconformably by Pliocene or Quaternary sediments, which are not discussed in this report.



STRUCTURAL GEOLOGY

REGIONAL SETTING

The Paducah 1°x 2° Quadrangle encompasses the east flank of the Ozark Dome, the south end of the Illinois Basin, and the north end of the Mississippi Embayment (fig. 6). The first two are features of the Paleozoic bedrock; the third contains Cretaceous and Cenozoic sedimentary rocks. The study area contains one of the most complexly faulted portions of the North American craton. The tectonic history involves several episodes of extension, compression, wrench faulting, and igneous activity.

The Ozark Dome encompasses much of southern Missouri and portions of northern Arkansas and southwesternmost Illinois. A generally stable, positive area throughout the Paleozoic Era, the Ozark Dome is overlapped by thinner strata than surrounding basins. In the Paducah Quadrangle the Ozark Dome is the region of Devonian and older rocks in the southwestern part of the area. Strata on the dome dip gently eastward or east-northeastward, and are displaced by numerous faults. The northeast margin of the Ozark Dome is a major fault zone, the Ste. Genevieve Fault Zone (fig. 6). South of the termination of this fault zone, the east margin of the dome is along a gentle monocline that approximately coincides with the outcrop belt of the New Albany Shale.

The Illinois Basin is an intracratonic depression that occupies much of Illinois, southwestern Indiana, and western Kentucky. The broad central part of the basin is called the Fairfield Basin, and is centered north of the eastern part of the Paducah Quadrangle. Much smaller in area is the Eagle Valley-Moorman Syncline, which extends eastward from Gallatin County, Illinois, into Kentucky (fig. 6). The syncline overlies a Cambrian graben and contains the thickest sedimentary succession in the Illinois Basin—about 23,000 feet

(Bretagne and Leising 1991). On the west margin of the basin is a broad area of gently dipping strata, the Sparta Shelf. The southeastern part of the Sparta Shelf is in the northwestern part of the study area.

The Mississippi Embayment began to form in Late Cretaceous time as an extension of the Gulf Coastal Plain. Cretaceous and Cenozoic rocks overlap the Ozark Dome and Illinois Basin at the north margin of the embayment (plate 1).

TECTONIC HISTORY

A failed rift bordered by large listric normal faults developed in the central Mississippi Valley early in the Cambrian Period. The rift comprises a northeast-trending segment, called the Reelfoot Rift, and an east-trending segment called the Rough Creek Graben. The junction of the two rift segments lies in the southeastern part of the Paducah Quadrangle. The northwest boundary of the Reelfoot Rift coincides with the Lusk Creek Fault Zone and its buried southwest extension. The Rough Creek-Shawneetown Fault System marks the north margin of the Rough Creek Graben; the Pennyrite Fault System approximately defines the south margin (Bretagne and Leising 1991, Nelson 1991).

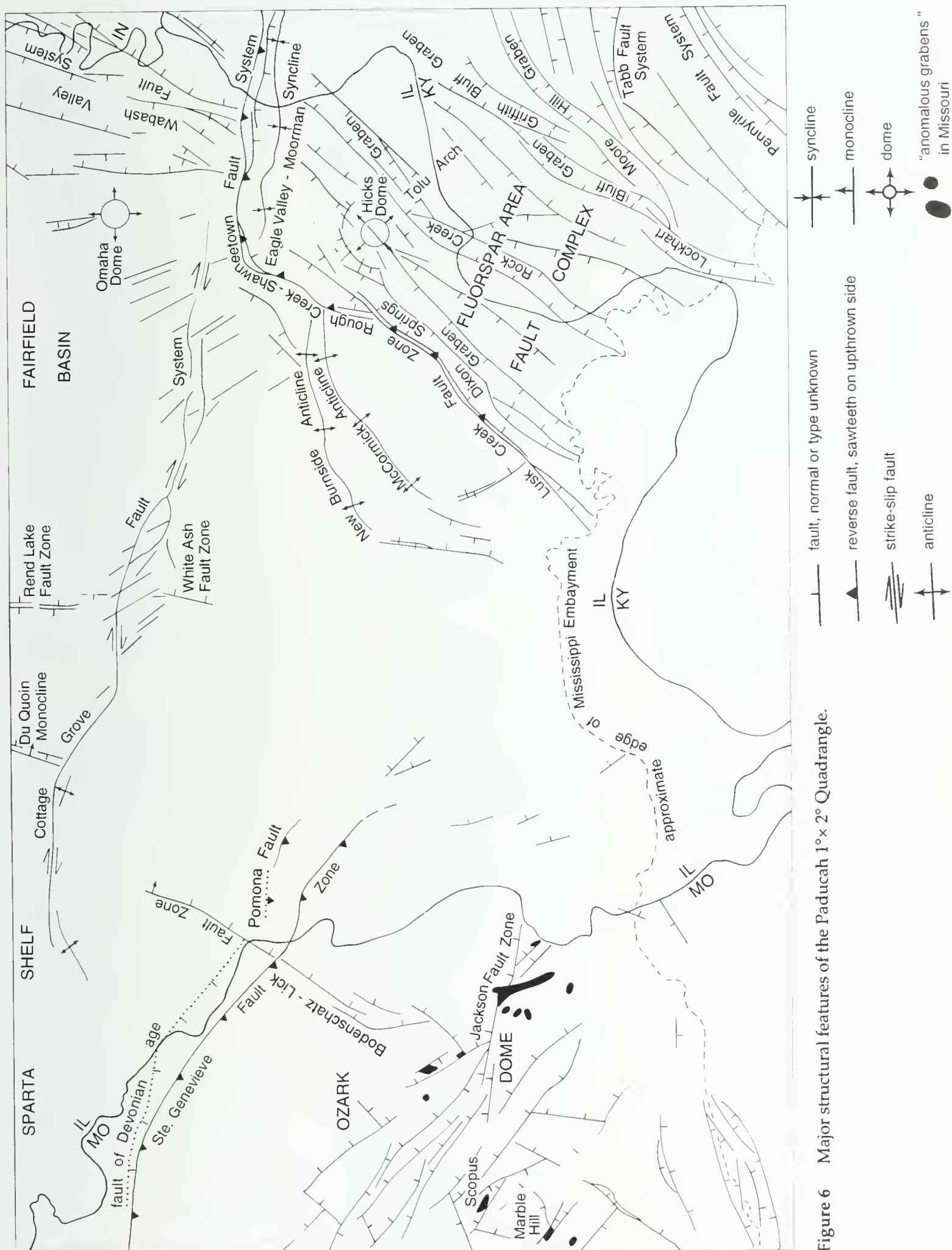
While surrounding areas underwent erosion, the Reelfoot Rift and Rough Creek Graben received thousands of feet of Cambrian sediments. Active faulting in the grabens ceased in Late Cambrian time, but the area centered near the junction of the grabens continued to subside rapidly (Howe and Thompson 1984, Kolata and Nelson 1991). Isopach patterns of many Paleozoic units, notably the Knox, Devonian, and Mississippian, reflect development of an elongate embayment or proto-Illinois Basin above the rift junction.

Normal faulting took place in the Devonian Period along the Ste. Genevieve Fault Zone, and possibly also on the eastern Ozark Dome.

Near the end of the Mississippian Period, the Ste. Genevieve Fault Zone was reactivated, this time as a reverse fault. Other structures in the study area, including the Du Quoin Monocline, were active at about the same time. Most faults in the Paducah Quadrangle, however, are Pennsylvanian or younger. Ultramafic rocks dated as Early Permian intruded in the eastern part of the quadrangle. Intrusion was accompanied by northwest-southeast compression that formed reverse and strike-slip faults and anticlines. Some of the rift-bounding normal faults were reactivated as reverse faults. Following compression was an episode of northwest-southeast extension. The many northeast-trending normal faults of the Fluorspar Area Fault Complex and Wabash Valley Fault System developed during this episode. Some of these normal faults were old faults rejuvenated, others were newly formed.

The Illinois Basin did not assume its present form until these movements were completed. Southern closure of the basin was caused by uplift of the Pascola Arch, a domal feature centered south of the Paducah Quadrangle (Schwalb 1982). The Pascola Arch was raised some time between Pennsylvanian and Late Cretaceous time.

The crest of the Pascola Arch was beveled by erosion prior to deposition of Cretaceous sediments in the Mississippi Embayment. Some northeast-trending faults in the study area were active into Cenozoic time. Post-Cretaceous displacements of these faults are small compared to pre-Cretaceous ones. The Paducah Quadrangle is immediately north of the North American Midcontinent's most active earthquake area, the New Madrid Seismic Zone. Contemporary tectonic stress in the region is believed responsible for some small faults, joints, and roof failures in underground coal mines (Nelson and Bauer 1987).



INDIVIDUAL STRUCTURES

Rough Creek-Shawneetown Fault System

This fault system enters the study area in Union County, Kentucky, runs westward to southeastern Saline County, Illinois, and turns sharply southwest to merge with the Lusk Creek Fault Zone (plate 1, fig. 6). In map view at the surface, the Rough Creek-Shawneetown is a narrow zone of faults that form a braided pattern. The master fault is a south-dipping, high-angle reverse fault; other faults diverge upward from the master fault to produce a "positive flower structure." Displacement across the fault zone as a whole is slight, but narrow slices of rock within the zone are upthrown as much as 3,500 feet (plate 4, section M-N). At least three episodes of displacement are indicated. The first was normal faulting during Cambrian rifting. The second was post-Pennsylvanian reverse faulting. The third was normal faulting (probably post-Permian, pre-Cretaceous). Rocks uplifted during the second episode were sheared off and left high within the fault zone during the third, extensional episode (Smith and Palmer 1974, Nelson and Lumm 1987, Bretagne and Leising 1991, Nelson 1991).

Lusk Creek Fault Zone The Lusk Creek Fault Zone extends as a zone of surface faults from northeastern Pope County, Illinois, to the edge of the Mississippi Embayment in Massac County (plate 1, fig. 6). The faults continue in Paleozoic rocks beneath the Embayment (Kolata et al. 1981). The Lusk Creek is a narrow zone of southeast-dipping, high-angle normal and reverse faults (plate 5, sections H-J, K-L). The net displacement is several hundred feet down to the southeast. Locally, narrow slices of older rocks are upthrown within the zone. The Lusk Creek and Rough Creek-Shawneetown have essentially identical histories: Cambrian normal faulting, post-Pennsylvanian reverse faulting, and early Mesozoic (?) normal faulting. The Lusk Creek Fault Zone marks the northwest margin of the Reelfoot Rift (Nelson 1991, Bretagne and Leising 1991, Nelson et al. 1991).

Pennyryle Fault System The Pennyryle Fault System crosses the

southeast corner of the Paducah Quadrangle and continues eastward across Kentucky (plate 1, fig. 6). It is a zone of high-angle normal faults with the major displacements down to the north (plate 5, section K-L). These faults approximately coincide with the south margin of the Rough Creek Graben (Bretagne and Leising 1991). The Pennyryle Fault System has been recurrently active from Cambrian to post-Pennsylvanian time (Lumm et al. 1991).

Fluorspar Area Fault Complex

This name is applied to the intricate network of faults in the Illinois-Kentucky fluorspar district (plate 1, fig. 6). The boundaries (counter clockwise) are Rough Creek-Shawneetown Fault System, Lusk Creek Fault Zone, edge of Mississippi Embayment, Pennyryle Fault System, and east edge of Paducah Quadrangle. The complex overlies the junction of the Reelfoot Rift and Rough Creek Graben. Elements of the Fluorspar Area Fault Complex are (1) northwest-trending faults and ultramafic dikes, (2) Hicks Dome and Tolu Arch, (3) radial and arcuate faults surrounding Hicks Dome, and (4) northeast-trending faults

The northwest-trending faults are vertical or high-angle faults of small displacement. They bear horizontal slickensides, indicating strike-slip movement (Hook 1974). Associated dikes are dated radiometrically as Early Permian (Zartman et al. 1967).

Hicks Dome is a slightly elliptical uplift in western Hardin County, Illinois (plate 1). Its structural relief exceeds 2,000 feet. Hicks Dome is near the northwest end of the Tolu Arch, a broad southeast-trending upwarp that is offset by numerous cross faults. Ultramafic dikes, small stocks, and diatremes radiate from the apex of Hicks Dome and follow the axis of the Tolu Arch. A test well near the apex of the dome encountered intensely brecciated and mineralized rock at depth (Brown et al. 1954). Hicks Dome has been interpreted as a "crypto-explosive" structure that may be the product of steam explosions caused by magma encountering groundwater (McGinnis and Bradbury 1964). Bradbury and Baxter (1992) interpreted shatter, vent, and carbonatitic breccias at Hicks Dome as products of explosive activity accompanied by intrusion of

alkaline igneous magma at depth, probably during Permian time.

Radial and arcuate faults have been mapped around the perimeter of Hicks Dome (plate 1). These faults have small displacements and probably formed during uplift of the dome.

Northeast-trending faults are largest and most numerous in the Fluorspar Area Fault Complex (plate 1; plate 5, sections H-J, K-L). They are dominantly high-angle normal faults that outline complex horsts and grabens, or they occur as sets of step faults that form braided patterns in map view. Displacements range from a few feet to as much as 2,400 feet. Rocks in grabens are tilted and folded into synclines, whereas strata in horsts generally retain their regional dip. This observation implies that the grabens apparently were the active elements, moving downward while horsts remained stationary (Trace and Amos 1984). A few high-angle reverse faults are present (Baxter and Desborough 1965, Baxter et al. 1967). Some faults display slickensides that indicate oblique slip (Weller et al. 1952, Trace 1974a, Hook 1974, Trace and Amos 1984). The northeast-trending faults are extensively mineralized. Multiple episodes of faulting and ore deposition are indicated.

The northwest-trending dikes and the faults they follow are Early Permian. The fact that dikes follow the Tolu Arch and radiate from Hicks Dome suggests that all these features formed at the same time. Northeast-trending faults offset dikes and therefore are younger. Most of the displacement and mineralization on northeast-trending faults occurred between Early Permian and Late Cretaceous times.

Displacement of Cretaceous strata along northeast-trending faults was documented in southern Livingston and Marshall Counties, Kentucky (Rhoades and Mistler 1941, Amos 1967, Amos and Finch 1968). Post-Cretaceous throws of about 100 feet contrast with throws as great as 2,400 feet in Paleozoic rocks along the same faults (plate 1). The strike-slip component of post-Cretaceous faulting is unknown. Faults in Ballard and western McCracken Counties, Kentucky, displace strata as young as Eocene (Olive 1969, Swanson 1978). In

southern Illinois, Kolata et al. (1981) described several examples of deformed Cretaceous and Tertiary sediments, but attributed deformation to nontectonic causes. New mapping (Nelson, in preparation; Devera and Nelson, in preparation) at the southwest end of the Dixon Springs Graben in Pope and Massac Counties, Illinois, uncovered tectonic faulting of Cretaceous and Tertiary strata. At two of these sites, not only the McNairy Formation (Cretaceous), but also the Mounds Gravel (Pliocene to early Pleistocene?), are displaced.

McCormick and New Burnside Anticlines These two anticlines are located northwest of the Lusk Creek Fault Zone in southeastern Illinois (plate 1, fig. 6). They are asymmetrical, having dips of 10° or less on the southeast flanks and dips of 20° to 24° on the northwest flanks (plate 4, section D-K). Many subparallel to en echelon faults have been mapped along both anticlines. Proprietary seismic data suggest that these folds are detached from basement. The folds may be due to early compression, whereas the faults are mostly products of later extension (Bristol 1975, Nelson et al. 1991, Nelson 1993).

Wabash Valley Fault System Located in the northeast corner of the Paducah Quadrangle, the Wabash Valley Fault System is composed of high-angle normal faults that strike north-south to northeast-southwest (plate 1; plate 4, section D-K; fig. 6). Displacements are up to 480 feet. Seismic profiles and borehole data indicate that faults commonly bifurcate upward (Bristol and Treworgy 1979, Ault et al. 1980). The time of faulting cannot be bracketed more closely than between Pennsylvanian and Quaternary.

Omaha Dome This feature, which lies at the west edge of the Wabash Valley Fault System (plate 1), is nearly circular and exhibits 150 to 200 feet of closure on Mississippian and younger rocks (Bristol 1975). Several oil-test holes on the dome have encountered ultrabasic igneous rock. A well at the apex penetrated three sills and reached total depth in the Muscatatuck Group at regional elevation (plate 4, section C-E). The

dome was formed by igneous intrusions into the New Albany Shale and younger strata (Nelson 1991).

Cottage Grove Fault System

This fault system trends slightly north of west across the northern part of the Paducah Quadrangle (plate 1). It is known in considerable detail from borehole data, seismic-reflection profiles, and exposures in underground coal mines. The master fault consists of upward-splitting reverse faults that outline "flower structures" in places (plate 2, section A-B; plate 4, sections D-K, M-N). The dip and direction of throw are inconsistent. Northwest-trending en echelon, normal, and oblique-slip faults flank the master fault. Also present are anticlines and domes, the axes of which lie en echelon along the master fault. The pattern of faults and folds indicates right-lateral wrenching (Clark and Royds 1948, Nelson and Krausse 1981). The faults displace upper Pennsylvanian strata, but they generally do not offset associated Early Permian ultramafic dikes (Nelson and Lumm 1987).

Rend Lake and White Ash

Fault Zones The Rend Lake and White Ash Fault Zones are north-trending fault zones that lie, respectively, north and south of the Cottage Grove Fault Zone just east of longitude 89° W (plate 1, fig. 6). They are composed of high-angle normal faults having maximum throws of about 50 feet (plate 4, section C-E). Because the faults are known mainly from exposures in coal mines, the vertical extent of the faults is unknown. Keys and Nelson (1980) related the Rend Lake zone to incremental uplift and subsidence of a basement fault block.

Du Quoin Monocline The south end of the Du Quoin Monocline is in the northeast corner of the Carbonate 30 × 60-minute quadrangle (plate 1). This east-facing flexure partly separates the Sparta Shelf from the Fairfield Basin. Relief increases with depth from about 550 feet on the Pennsylvanian Herrin Coal to 1,000 feet on Mississippian and older strata (plate 2, section B-C). Hence, the monocline developed concurrently with Pennsylvanian sedimentation (Siever 1951).

The Dowell Fault Zone parallels the axis of the Du Quoin Monocline (plate 1, fig. 6). The zone is composed of high-angle normal faults that have maximum throw of about 40 feet. Most of the faults dip westward (Nelson and Krausse 1981).

Ste. Genevieve Fault Zone The Ste. Genevieve Fault Zone trends southeastward, partly separating the Ozark Dome from the Illinois Basin (plate 1, fig. 6). It is one of the major fault zones of the region. The Ste. Genevieve underwent two periods of movement with opposite sense of displacement.

Surface faults are largely, if not entirely, post-Mississippian. They form a braided pattern in map view and dip 60° or steeper. The largest faults of the zone are southwest-dipping reverse faults (Flint 1926, S. Weller and St. Clair 1928, Gibbons 1974). Accompanying the fault zone is a northeast-facing monocline, along which bedding is locally vertical or overturned (Amos 1985a, c). Total relief of the fault zone and monocline is about 3,000 feet along most of the length of the zone. Surficial faulting terminates abruptly in northern Union County, Illinois, and the monocline becomes broad and gentle.

Sedimentological evidence suggests that the surface structures began to develop during deposition of the Pennsylvanian Caseyville Formation (Poor 1925, Desborough 1961b). Post-Caseyville movement probably occurred but cannot be documented because rocks of this age are not present along the fault zone. The Ste. Genevieve has been described as a compressive-block structure analogous to Laramide uplifts of the Rocky Mountain foreland (Tikrity 1968, Gibbons 1974, Nelson and Lumm 1985, Clendenin et al. 1989). Several authors, including Heyl (1972), Viele (1983), and Clendenin et al. (1989) have postulated significant strike-slip displacement of the Ste. Genevieve Fault Zone.

Part of the Ste. Genevieve Fault Zone was active during the Devonian Period and created displacement opposite to post-Mississippian displacements. Devonian faulting first was recognized by S. Weller and St. Clair (1928) in outcrops in Ste. Genevieve County, Missouri, west of the Paducah Quadrangle. Subsurface evidence for this faulting exists

within the study area (plate 2, section A-B). The Devonian fault is concealed by younger deposits beneath the Mississippi River floodplain a short distance northeast of the main fault zone. The Devonian fault, indicated by a dotted line on geologic map (plate 1), has displacement down to the southwest. Northeast of this fault, the basal Mississippian Fern Glen Formation rests on thin New Albany Shale, which in turn, unconformably overlies Lower Devonian or Silurian strata. In the narrow slice between the Devonian and post-Mississippian faults, the New Albany is of normal thickness and lies with slight disconformity on Middle Devonian strata (plate 2, section A-B). The indicated time of movement is late Middle Devonian and Late Devonian (Nelson and Lumm 1985).

Pomona Fault The Pomona Fault in southern Jackson County, Illinois, is part of the Ste. Genevieve Fault Zone. The Pomona Fault runs parallel with and lies 3 to 5 miles northeast of the large faults described above (plate 1, fig. 6). Desborough (1961a) mapped the Mississippian and Pennsylvanian rocks as downthrown northeast of the Pomona Fault. Recent mapping indicates that Mississippian rocks are faulted and that Pennsylvanian strata are merely folded, implying post-Mississippian and pre-Pennsylvanian faulting followed by post-Pennsylvanian flexure (Devera and Nelson 1995). In a study of jointing along the Pomona Fault, Johnson (1970) concluded that reverse faulting took place under northeast-southwest compression.

A large number of north-trending faults were mapped in the area southwest of the Pomona Fault. These faults outline tilted blocks of Chesterian strata unconformably overlain by horizontal Caseyville Formation. New mapping (Devera and Nelson 1995) indicates that these are large-scale rotational slump blocks.

Bodenschatz-Lick Fault Zone

The Bodenschatz-Lick Fault was first identified in Perry County, Missouri (Flint 1925). Later mapping revealed a fault zone that extends across the Ste. Genevieve Fault Zone into Jackson County, Illinois (plate 1, fig. 6). In the Neelys Landing and

Oak Ridge Quadrangles, a complicated pattern of faults and monoclines deforms Ordovician through Lower Devonian rocks. Projection of the fault zone into Illinois is based on well data, which show several hundred feet of offset on Mississippian and older units. A monocline (maximum dip 12°–14°) but no faulting is apparent from outcrops of Pennsylvanian rocks in the Oraville Quadrangle (Kolesar 1964, Nelson and Lumm 1985).

Available evidence thus indicates that at least some of the movement was post-Mississippian. The style of deformation and relation to regional tectonics are unclear.

Northwest-trending faults on the Ozark Dome

Northwest-trending faults are abundant throughout the Ozark Dome in the Missouri part of the study area (plate 1, fig. 6). Most of these faults are downthrown to the northeast, although a few are downthrown to the southwest and outline horst and grabens. Displacements range from a few feet to about 200 feet. No details on the attitudes of the fault planes or sense of displacement are available. The gentle dips, general absence of folding, and the nearly straight courses of faults across rugged terrain suggest that they are more likely high-angle normal faults rather than thrust or reverse faults. Strike-slip movement cannot be ruled out, particularly on the Jackson Fault Zone, which strikes N80°W through the city of Jackson (plate 1; plate 3, section F-G). Swarms of curving northwest-trending faults branch off both ends of the Jackson Fault Zone. Such a fault pattern suggests right-lateral strike-slip. Clendenin et al. (1989) reported evidence for right-lateral movement on several large northwest-trending faults northwest of the Cape Girardeau Quadrangle. Northwest-trending faults displace rocks ranging in age from Canadian to Lower Devonian.

Northeast-trending faults in Missouri

Northeast-trending faults in Missouri are common on Crowley's Ridge and nearby hills and on the east end of the Benton Hills, where several faults cross into Illinois (plate 1). Northeast-trending faults also are present, although less numerous, among the northwest-

trending faults in bedrock uplands north of the Mississippi Embayment. Kolata et al. (1981) mapped several northeast-trending faults in Paleozoic rocks, beneath Cretaceous and Tertiary cover, in southern Pulaski County, Illinois. These faults are not depicted on the geologic map.

North-northwest-trending faults displace Cretaceous and Tertiary sediments at a number of sites. The McNairy Formation is down-dropped into northeast-trending grabens in the Dongola (Amos 1981a) and Marble Hill (Amos 1987a) Quadrangles (plate 1). Young faulting is pronounced along Crowley's Ridge (southwest corner of plate 1) and in the Benton Hills of northern Scott County, Missouri. Units as young as the Mounds Gravel (Pliocene–early Pleistocene?) are folded and faulted in the Thebes Quadrangle, Missouri-Illinois. Northeast-trending faults at Thebes Gap outline narrow pull-apart structures and apparently are products of right-lateral wrenching (Harrison and Schultz 1992, Nelson and Harrison 1993, Harrison, in preparation). Quaternary loess is faulted against the Wilcox Formation in Section 34, T29N, R14E, Scott County (McCracken 1971, p. 28).

The timing and structural style of faulting outlined above are consistent with contemporary stress and tectonic faulting in the New Madrid Seismic Zone, immediately south of the Paducah Quadrangle.

North-northwest-trending faults in southwestern Illinois

Several of these faults were mapped in western Union and Alexander Counties, Illinois (plate 1, fig. 6). Another such fault occurs beneath Quaternary alluvium in northwestern Pulaski County (Kolata et al. 1981). Faults that trend north-northwest dip steeply, and the majority have the east sides downthrown. Drag and slickensides along the Atwood and Delta Faults indicate dip-slip normal faulting; but en echelon fractures and flower structures associated with the Cape Road Fault suggest dextral strike-slip. Some of these faults displace units as young as Eocene (Nelson et al. 1995). The narrow strip of undivided Cretaceous and Tertiary strata, north of the Mississippi Embayment in Union and Alexander Counties,

trends north-northwest and is at least partially bordered by faults.

Anomalous grabens and breccia pipes Numerous narrow grabens exhibiting unusually large vertical displacements were mapped in Paleozoic bedrock on the Ozark Dome in Missouri (plate 1, fig. 6). Named features include the Marble Hill and Scopus structures near the west edge of the quadrangle and the Radio Tower and Randol Creek structures near Cape Girardeau (McCracken 1971). Additional newly mapped anomalous grabens lie within, near, and south of the Jackson Fault Zone in and near Cape Girardeau and in the Thebes Quadrangle south of Cape Girardeau (Harrison, in preparation).

The structures are elongate wedge- or lozenge-shaped or elliptical grabens, commonly a few ten to a few hundred feet wide, and up to a few thousand feet long. Largest is the Scopus structure, 2,400 by 10,000 feet (Amos 1987b). The structures occur within various Ordovician formations and contain blocks of Upper Ordovician, Silurian, and Lower Devonian rocks. Many of the structures contain Bailey Limestone,

but none contain younger Paleozoic rocks. A slice of Cretaceous McNairy Formation is mapped in the Scopus structure. Grabens in the Thebes Quadrangle contain McNairy, Wilcox, and possibly Mounds strata. In the Marble Hill structure, Bailey Limestone has been downdropped 2,400 feet against Cotter Dolomite. In the Scopus structure, the Moccasin Springs Formation is displaced 1,900 feet vertically against Smithville/Powell Dolomites (Amos 1987b). These large displacements contrast with modest offsets on nearby faults. Some of the anomalous structures contain large, apparently intact tilted blocks, whereas others contain disordered blocks or slices having various attitudes.

Many of the anomalous grabens are located along northwest-trending faults. Some of them lie within longer, narrow grabens bounded by cross faults that trend north or northeast. In the Thebes Quadrangle most of the grabens trend northeast.

Possibly related to the grabens is the breccia pipe mapped by Amos (1982a) in the Millersville Quadrangle about 7 miles northwest of Jackson, Missouri, and three smaller pipes southeast of Jackson in the

Gordonville Quadrangle (Amos 1985d). All contain sedimentary rock fragments, including chert from the Bailey Limestone, in a matrix of dark red plastic clay. The Millersville breccia pipe is largest, about 800 feet in diameter. Contacts with wall rocks are not exposed, but they are probably sharp. All of the pipes occur along small faults, which have a variety of trends. No igneous rock, contact metamorphism, or hydrothermal alteration was observed.

Solution collapse was suggested as a possible origin of the grabens and breccia pipe (McCracken 1971). Solution alone, however, appears inadequate to explain the large displacements involved in some of these structures. Moreover, the cherty dolomites that serve as wall rocks for many of the grabens are not prone to solution at such a grand scale. Grabens in the Thebes Quadrangle clearly are of tectonic origin. They occur along northeast-trending fault zones, which bear fold and fracture patterns indicating dextral strike-slip. These grabens probably are pull-apart structures or negative flower structures associated with wrenching (Harrison and Schultz 1992, Nelson and Harrison 1993).



REFERENCES

This list contains all references cited on the bedrock geologic map (plate 1), stratigraphic columns, and cross sections (plates 2–5), as well as references made in this report.

- Amos, D.H., 1965, *Geology of the Shetlerville and Rosiclare Quadrangles, Livingston and Crittenden Counties, Kentucky*: U.S. Geological Survey Geologic Quadrangle Map GQ-400, scale 1:24,000.
- Amos, D.H., 1966, *Geologic Map of the Golconda and Brownfield Quadrangles, Livingston County, Kentucky*: U.S. Geological Survey Geologic Quadrangle Map GQ-546, scale 1:24,000.
- Amos, D.H., 1967, *Geologic Map of the Smithland Quadrangle, Livingston County, Kentucky*: U.S. Geological Survey Geologic Quadrangle Map GQ-657, scale 1:24,000.
- Amos, D.H., 1974, *Geologic Map of the Burna Quadrangle, Livingston County, Kentucky*: U.S. Geological Survey Geologic Quadrangle Map GQ-1150, scale 1:24,000.
- Amos, D.H., 1981a, *Geologic Map of the Dongola Quadrangle, Bollinger and Stoddard Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1363, scale 1:24,000.
- Amos, D.H., 1981b, *Geologic Map of the Whitewater Quadrangle, Bollinger and Cape Girardeau Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1256, scale 1:24,000.
- Amos, D.H., 1981c, *Geologic Map of the Chaffee Quadrangle, Scott and Cape Girardeau Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1316, scale 1:24,000.
- Amos, D.H., 1982a, *Geologic Map of the Millersville Quadrangle, Cape Girardeau and Bollinger Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1459, scale 1:24,000.
- Amos, D.H., 1982b, *Geologic Map of the Burfordville Quadrangle, Cape Girardeau and Bollinger Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1385, scale 1:24,000.
- Amos, D.H., 1984, *Geologic Map of the Sedgewickville Quadrangle, Bollinger and Perry Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1674, scale 1:24,000.
- Amos, D.H., 1985a, *Geologic Map of the Crosstown 7½-Minute Quadrangle, Perry County, Missouri*: Missouri Geological Survey, Open File Map OFM-85-222-GI, scale 1:24,000.
- Amos, D.H., 1985b, *Geologic Map of the Rockwood 7½-Minute Quadrangle, Perry County, Missouri*: Missouri Geological Survey, Open File Map OFM-85-223-GI, scale 1:24,000.
- Amos, D.H., 1985c, *Geologic Map of the Altenburg 7½-Minute Quadrangle, Perry County, Missouri*: Missouri Geological Survey, Open File Map OFM-85-221-GI, scale 1:24,000.
- Amos, D.H., 1985d, *Geologic Map of the Gordonville Quadrangle, Cape Girardeau County, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1823, scale 1:24,000.
- Amos, D.H., 1986a, *Geologic Map of the Belgique 7½-Minute Quadrangle, Perry County, Missouri*: Missouri Geological Survey, Open File Map OFM-86-234-GI, scale 1:24,000.
- Amos, D.H., 1986b, *Geologic Map of the Kaskaskia 7½-Minute Quadrangle, Ste. Genevieve County, Missouri*: Missouri Geological Survey, Open File Map OFM-86-232-GI, scale 1:24,000.
- Amos, D.H., 1986c, *Geologic Map of the Lithium 7½-Minute Quadrangle, Perry and Ste. Genevieve Counties, Missouri*: Missouri Geological Survey, Open File Map OFM-86-233-GI, scale 1:24,000.
- Amos, D.H., 1986d, *Geologic Map of the Perryville East 7½-Minute Quadrangle, Perry County, Missouri*: Missouri Geological Survey, Open File Map OFM-86-236-GI, scale 1:24,000.
- Amos, D.H., 1987a, *Geologic Map of the Marble Hill Quadrangle, Bollinger County, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1900, scale 1:24,000.
- Amos, D.H., 1987b, *Geologic Map of the Scopus Quadrangle, Bollinger County, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1910, scale 1:24,000.
- Amos, D.H., 1987c, *Geologic Map of the Jackson Quadrangle, Cape Girardeau County, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1935, scale 1:24,000.
- Amos, D.H., 1987d, *Geologic Map of the Friedheim Quadrangle, Cape Girardeau, Bollinger and Perry Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1905, scale 1:24,000.
- Amos, D.H., and D.D. Blankenship, 1980a, *Geologic Map of the Bell City Quadrangle, Stoddard and Scott Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1206, scale 1:24,000.
- Amos, D.H., and D.D. Blankenship, 1980b, *Geologic Map of the Advance Quadrangle, Stoddard and Bollinger Counties, Missouri*: U.S. Geological Survey Miscellaneous Field Studies Map MF-1197, scale 1:24,000.
- Amos, D.H., and W.I. Finch, 1968, *Geologic Map of the Calvert City Quadrangle, Livingston and Marshall Counties, Kentucky*: U.S. Geological Survey Geologic Quadrangle Map GQ-731, scale 1:24,000.

- Amos, D.H., and W.H. Hays, 1974, Geologic Map of the Dycusburg Quadrangle, Crittenden, Livingston and Lyon Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1149, scale 1:24,000.
- Amos, D.H., and E.W. Wolfe, 1966, Geologic Map of the Little Cypress Quadrangle, Livingston, Marshall and McCracken Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-554, scale 1:24,000.
- Anderson, K.H., coordinator, 1979, Geologic Map of Missouri: Missouri Geological Survey, scale 1:500,000.
- Ault, C.H., D.M. Sullivan, and G.F. Tanner, 1980, Faulting in Posey and Gibson Counties, Indiana: Proceedings of the Indiana Academy of Science, v. 89, p. 275–289.
- Baxter, J.W., and G.A. Desborough, 1965, Areal Geology of the Illinois Fluorspar District, Part 2—Karbbers Ridge and Rosiclare Quadrangles: Illinois State Geological Survey, Circular 385, 40 p.
- Baxter, J.W., G.A. Desborough, and C.W. Shaw, 1967, Areal Geology of the Illinois Fluorspar District, Part 3—Herod and Shetlerville Quadrangles: Illinois State Geological Survey, Circular 413, 41 p.
- Baxter, J.W., P.E. Potter, and F.L. Doyle, 1963, Areal Geology of the Illinois Fluorspar District, Part 1—Saline Mines, Cave in Rock, De Koven, and Repton Quadrangles: Illinois State Geological Survey, Circular 342, 43 p.
- Becker, L.E., and J.B. Droste, 1978, Late Silurian and Early Devonian Sedimentologic History of Southwestern Indiana: Indiana Geological Survey, Occasional Paper 24, 14 p.
- Berg, R.B., and J.M. Masters, 1994, Geology of Microcrystalline Silica (Tripoli) Deposits, Southernmost Illinois: Illinois State Geological Survey, Circular 555, 84 p.
- Borden, W.W., 1874, Report of a geological survey of Clark and Floyd Counties, Indiana: Indiana Geological Survey, Annual Report 5, p. 133–189.
- Bradbury, J.C., and J.W. Baxter, 1992, Intrusive Breccias at Hicks Dome, Hardin County, Illinois: Illinois State Geological Survey, Circular 550, 23 p.
- Bretagne, A.C., and T.C. Leising, 1991, Interpretation of seismic data from the Rough Creek Graben of western Kentucky and southern Illinois, in M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, editors, Interior Cratonic Basins: American Association of Petroleum Geologists Memoir 51, p. 199–208.
- Bristol, H.M., 1975, Structural Geology and Oil Production of Northern Gallatin County and Southernmost White County, Illinois: Illinois State Geological Survey, Illinois Petroleum 105, 20 p.
- Bristol, H.M., and R.H. Howard, 1971, Paleogeologic Map of the Sub-Pennsylvanian (Upper Mississippian) Surface in the Illinois Basin: Illinois State Geological Survey, Circular 458, 16 p.
- Bristol, H.M., and J.D. Treworgy, 1979, The Wabash Valley Fault System in Southeastern Illinois: Illinois State Geological Survey, Circular 509, 19 p.
- Brown, J.S., J.A. Emery, and P.A. Meyer, 1954, Explosion pipe in test well on Hicks Dome, Hardin County, Illinois: Economic Geology, v. 49, no. 8, p. 891–902.
- Buschbach, T.C., 1964, Cambrian and Ordovician Strata of Northeastern Illinois: Illinois State Geological Survey, Report of Investigations 218, 90 p.
- Butts, Charles, 1917, Descriptions and Correlations of the Mississippian Formations of Western Kentucky: Kentucky Geological Survey, v. 1, 119 p.
- Clark, S.K., and J.S. Royds, 1948, Structural trends and fault systems in Eastern Interior Basin: Bulletin of American Association of Petroleum Geologists, v. 32, no. 9, p. 1728–1749.
- Clendenin, C.W., C.A. Niewendorp, and G.R. Lowell, 1989, Reinterpretation of faulting in southeast Missouri: Geology, v. 17, no. 3, p. 217–220.
- Cluff, R.M., J.A. Lineback, R.M. Lloyd, and C. Gum, 1981, Middle Mississippian Carbonates of the Illinois Basin—A Seminar and Core Workshop: Illinois Geological Society, Mt. Vernon, IL, 88 p.
- Cluff, R.M., M.L. Reinbold, and J.A. Lineback, 1981, The New Albany Shale Group of Illinois: Illinois State Geological Survey, Circular 518, 83 p.
- Collinson, Charles, L.E. Becker, G.W. James, J.W. Koenig, and D.H. Swann, 1967, Devonian of the north-central region, United States, in International Symposium on the Devonian System: Alberta Society of Petroleum Geologists, v. 1, p. 933–971.
- Collinson, Charles, M.L. Sargent, and J.R. Jennings, 1988, Illinois Basin region, in L.L. Sloss, editor, Sedimentary Cover, North American Craton, U.S.: Geological Society of America, The Geology of North America, v. D-2, p. 383–426.
- Croneis, Carey, 1944, The Devonian of Southern Missouri: Illinois State Geological Survey, Bulletin 68, p. 103–131.
- Desborough, G.A., 1961a, Geology of the Pomona Quadrangle, Illinois: Illinois State Geological Survey, Circular 320, 16 p.
- Desborough, G.A., 1961b, Sedimentational and structural dating of Rattlesnake Ferry Fault in southwestern Illinois: American Association of Petroleum Geologists Bulletin, v. 45, no. 8, p. 1401–1411.
- Devera, J.A., 1991, Geologic Map of the Glendale Quadrangle, Johnson and Pope Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 9, scale 1:24,000.
- Devera, J.A., 1993, Geologic Map of the Wolf Lake Quadrangle, Jackson and Union Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 13, scale 1:24,000.
- Devera, J.A., and W.J. Nelson, 1995, Geologic Map of the Cobden Quadrangle, Jackson and Union Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 16, scale 1:24,000.
- Devera, J.A., and W.J. Nelson, in preparation, Geologic Map of the Mermet Quadrangle, Johnson and Massac Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Series, scale 1:24,000.
- Devera, J.A., C.E. Mason, and R.A. Peppers, 1987, A marine shale in the Caseyville Formation (Lower Pennsylvanian) in southern Illinois: Geological Society of America, Abstracts with Programs, v. 19, no. 4, p. 220.
- DeWolf, F.W., 1910, Studies of Illinois coal—Introduction, in Year-Book for 1909: Illinois State

- Geological Survey, Bulletin 16, p. 178–181.
- Dial, D.C., 1963, The geology of the northwest quarter of the Vienna Quadrangle: M.S. thesis, Southern Illinois University, Carbondale, 66 p.
- Droste, J.B., and J.B. Patton, 1985, Lithostratigraphy of the Sauk Sequence in Indiana: Indiana Geological Survey, Occasional Paper 47, 24 p.
- Finch, W.I., 1966, Geologic Map of the Paducah West and Metropolis Quadrangles, McCracken County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-557, scale 1:24,000.
- Finch, W.I., 1967, Geologic Map of the Joppa Quadrangle, McCracken County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-652, scale 1:24,000.
- Flint, R.F., 1925, Geology of parts of Perry and Cape Girardeau Counties, Missouri: Ph.D. dissertation, University of Chicago, Illinois.
- Flint, R.F., 1926, Thrust-faults in southeastern Missouri: *American Journal of Science*, v. 12, p. 37–40.
- Gause, J.C., 1966, Areal geology of the Reevesville Quadrangle: M.S. thesis, Southern Illinois University, Carbondale, 137 p.
- Gibbons, J.F., 1974, Tectonics of the eastern Ozarks area, southeastern Missouri: Ph.D. thesis, Syracuse University, New York.
- Gray, H.H., R.D. Jenkins, and R.M. Weidman, 1960, Geology of the Huron area, south-central Indiana: Indiana Geological Survey, Bulletin 20, 78 p.
- Harrison, R.W., in preparation, Geologic Map of the Thebes Quadrangle, Missouri-Illinois: U.S. Geological Survey Geologic Quadrangle Map, scale 1:24,000.
- Harrison, R.W., and A.P. Schultz, 1992, Faulting at Thebes Gap, Missouri-Illinois: Implications for New Madrid Tectonism: *Geological Society of America, Abstracts with Programs*, p. 190.
- Hays, W.H., 1964, Geology of the Grand Rivers Quadrangle, Lyon and Livingston Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-328.
- Heyl, A.V., Jr., 1972, The 38th Parallel Lineament and its relationship to ore deposits: *Economic Geology*, v. 67, p. 879–894.
- Hook, J.W., 1974, Structure of the fault systems in the Illinois-Kentucky fluorspar district, in D.W. Hutcheson, editor, *A Symposium on the Geology of Fluorspar: Kentucky Geological Survey, Series X, Special Publication 22*, p. 77–86.
- Howe, J.R., and T.L. Thompson, 1984, Tectonics, sedimentation, and hydrocarbon potential of the Reelfoot Rift: *Oil and Gas Journal*, November 12, 1984, p. 179–190.
- Howe, W.B., and J.W. Koenig, 1961, The Stratigraphic Succession in Missouri: Missouri Geological Survey, 2nd Series, Vol. XL, 185 p.
- Jacobson, R.J., 1991, Geologic Map of the Goreville Quadrangle, Johnson and Williamson Counties Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 7, scale 1:24,000.
- Jacobson, R.J., and C.P. Weibel, 1993, Geologic Map of the Makanda Quadrangle, Jackson, Union, and Williamson Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 11, scale 1:24,000.
- Jennings, J.R., and G.H. Fraunfelder, 1986, Preliminary report on macropaleontology of strata above and below the upper boundary of the type Mississippian: *Transactions of the Illinois State Academy of Science*, v. 79, nos. 3, 4, p. 253–261.
- Johnson, V.C., 1970, Fracture patterns along the Pomona Fault, Jackson County, Illinois: M.S. thesis, Southern Illinois University, Carbondale, 42 p.
- Johnson, W.D., 1985a, Geologic Map of the Scott City Quadrangle and Part of the Thebes Quadrangle, Scott and Cape Girardeau Counties, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1803, scale 1:24,000.
- Johnson, W.D., 1985b, Geologic Map of the Oran Quadrangle, Scott and Stoddard Counties, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1804, scale 1:24,000.
- Johnson, W.D., 1985c, Geologic Map of the Morley Quadrangle, Scott County, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1805, scale 1:24,000.
- Kehn, T.M., 1973, Sturgis Formation (Upper Pennsylvanian), A New Map Unit in the Western Kentucky Coal Field: U.S. Geological Survey Bulletin 1394-B, 24 p.
- Kehn, T.M., 1974, Geologic Map of the Dekoven and Saline Mines Quadrangles, Crittenden and Union Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1147, scale 1:24,000.
- Kehn, T.M., J.G. Beard, and A.D. Williamson, 1982, Mauzy Formation, A New Stratigraphic Unit of Permian Age in Western Kentucky: U.S. Geological Survey Bulletin 1529-H, p. H73–H86.
- Keys, J.N., and W.J. Nelson, 1980, The Rend Lake Fault System in Southern Illinois: Illinois State Geological Survey, Circular 513, 23 p.
- Kolata, D.R., J.K. Frost, and W.D. Huff, 1986, K-bentonites of the Ordovician Decorah Subgroup, Upper Mississippian Valley: Correlation by Chemical Fingerprinting: Illinois State Geological Survey, Circular 537, 30 p.
- Kolata, D.R., and W.J. Nelson, 1991, Tectonic history of the Illinois Basin, in M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, editors, *Interior Cratonic Basins: American Association of Petroleum Geologists Memoir 51*, p. 263–285.
- Kolata, D.R., J.D. Treworgy, and J.M. Masters, 1981, Structural Framework of the Mississippi Embayment of Southern Illinois: Illinois State Geological Survey, Circular 516, 38 p.
- Kolesar, J.C., 1964, Geology of the southwest quarter of the Murphysboro Quadrangle, Illinois: M.S. thesis, Southern Illinois University, Carbondale, 84 p.
- Kosanke, R.M., J.A. Simon, H.R. Wanless, and H.B. Willman, 1960, Classification of the Pennsylvanian Strata of Illinois: Illinois State Geological Survey, Report of Investigations 214, 84 p.
- Lamar, J.E., 1925, Geology and Mineral Resources of the Carbondale Quadrangle: Illinois State Geological Survey, Bulletin 48, 172 p.
- Lineback, J.A., 1966, Deep-Water Sediments Adjacent to the Borden Siltstone (Mississippian) Delta in Southern Illinois: Illinois State Geological Survey, Circular 401, 48 p.
- Lineback, J.A., 1972, Lateral Gradation of the Salem and St. Louis

- Limestones (Middle Mississippian) in Illinois: Illinois State Geological Survey, Circular 474, 21 p.
- Lineback, J.A., 1981, The Eastern Margin of the Burlington-Keokuk (Valmeyeran) Carbonate Bank in Illinois: Illinois State Geological Survey, Circular 520, 24 p.
- Lumm, D.K., W.J. Nelson, and S.F. Greb, 1991, Structure and chronology of part of the Pennyryle Fault System, western Kentucky: *Southeastern Geology*, v. 32, no. 1, p. 43–59.
- Maples, C.G., and J.A. Waters, 1987, Redefinition of the Meramecian/Chesterian boundary (Mississippian): *Geology*, v. 15, p. 647–651.
- Martin, J.A., R.D. Knight, and W.C. Hayes, 1961, Ordovician System, in W.B. Howe, coordinator, *The Stratigraphic Succession in Missouri: Division of Geological Survey and Water Resources*, 2nd Series, Vol. XL, p. 20–31.
- McCormick, L.M., 1967, Bedrock geology of the NW¼ of the Dongola Quadrangle: M.S. thesis, Southern Illinois University, Carbondale, 114 p.
- McCracken, M.H., 1971, Structural Features of Missouri: Missouri Geological Survey and Water Resources, Report of Investigations 49, 99 p.
- McDowell, R.C., editor, 1986, *The Geology of Kentucky—A Text to Accompany the Geologic Map of Kentucky*: U.S. Geological Survey Professional Paper 1151-H, 76 p.
- McDowell, R.C., G.J. Grabowski, Jr., and S.L. Moore, 1981, *Geologic Map of Kentucky*: U.S. and Kentucky Geological Surveys, scale 1:250,000, 4 sheets.
- McFarlan, A.C., D.H. Swann, F.H. Walker, and Edmund Nosow, 1955, Some Old Chester Problems—Correlations of Lower and Middle Chester Formations of Western Kentucky: Kentucky Geological Survey, Series 9, Bulletin 16, 37 p.
- McGinnis, L.D., and J.C. Bradbury, 1964, Aeromagnetic Study of the Hardin County Area, Illinois: Illinois State Geological Survey, Circular 363, 12 p.
- Meents, W.F., and D.H. Swann, 1965, Grand Tower Limestone (Devonian) of Southern Illinois: Illinois State Geological Survey, Circular 389, 34 p.
- Middendorf, M.A., 1991, Bedrock Geologic Map of the Ware 7½-Minute Quadrangle, Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-91-261-GI, scale 1:24,000.
- Middendorf, M.A., and J.W. Whitfield, 1991a, Bedrock Geologic Map of the Oak Ridge 7½-Minute Quadrangle, Cape Girardeau and Perry Counties, Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-91-260-GI, scale 1:24,000.
- Middendorf, M.A., and J.W. Whitfield, 1991b, Bedrock Geologic Map of the Perryville West 7½-Minute Quadrangle, Perry County, Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-91-262-GI, scale 1:24,000.
- Middendorf, M.A., J.W. Whitfield, and C.E. Robertson, 1989, Bedrock Geologic Map of Cape Girardeau Northeast 7½-Minute Quadrangle, Cape Girardeau County, Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-89-253-GI, scale 1:24,000.
- Miller, A.M., 1917, Table of Geological Formations of Kentucky: University Bookstore, 7 p. Reprinted in A.M. Miller, 1919, *Geology of Kentucky*: Kentucky Geological Survey, Series V, Bulletin 2, p. 9–15.
- Miller, A.M., 1919, *Geology of Kentucky*: Kentucky Geological Survey, Series V, Bulletin 2, 392 p.
- Nelson, W.J., in preparation, Geologic Map of the Reevesville Quadrangle, Johnson, Massac, and Pope Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Series, scale 1:24,000.
- Nelson, W.J., 1991, Structural styles of the Illinois Basin, in: M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, editors, *Interior Cratonic Basins: American Association of Petroleum Geologists, Memoir 51*, p. 209–243.
- Nelson, W.J., 1993, Geology of the Bloomfield Quadrangle, Johnson County, Illinois: Illinois State Geological Survey, Bulletin 99, 30 p.
- Nelson, W.J., 1995, Geologic Map of the Bloomfield Quadrangle, Johnson County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 10, scale 1:24,000.
- Nelson, W.J., 1995, Structural Features of Illinois: Illinois State Geological Survey, Bulletin 100, 143 p.
- Nelson, W.J., and R.A. Bauer, 1987, Thrust faults in southern Illinois Basin—Result of contemporary stress?: *Geological Society of America Bulletin*, v. 98, p. 302–307.
- Nelson, W.J., J.A. Devera, and J.M. Masters, 1995, Geology of the Jonesboro 15-Minute Quadrangle, Southwestern Illinois—Jonesboro, Mill Creek, Ware, and McClure 7.5-Minute Quadrangles: Illinois State Geological Survey, Bulletin 101, 57 p.
- Nelson, W.J., and R.W. Harrison, 1993, Post-Cretaceous at head of Mississippi Embayment: Geological Society of America, Abstracts with Programs, North-Central Section, p. 69–70.
- Nelson, W.J., and H.-F. Krausse, 1981, The Cottage Grove Fault System in Southern Illinois: Illinois State Geological Survey, Circular 522, 65 p.
- Nelson, W.J., and D.K. Lumm, 1985, The Ste. Genevieve Fault Zone, Missouri and Illinois: Illinois State Geological Survey, Contract/Grant Report 1985-3, 94 p.
- Nelson, W.J., and D.K. Lumm, 1986a, Geologic Map of the Shawneetown Quadrangle, Gallatin County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 1, scale, 1:24,000.
- Nelson, W.J., and D.K. Lumm, 1986b, Geologic Map of the Equality Quadrangle, Gallatin and Saline Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 2, scale, 1:24,000.
- Nelson, W.J., and D.K. Lumm, 1986c, Geologic Map of the Rudement Quadrangle, Saline County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 3, scale, 1:24,000.
- Nelson, W.J., and D.K. Lumm, 1987, Structural Geology of Southeastern Illinois and Vicinity: Illinois State Geological Survey, Circular 538, 70 p.
- Nelson, W.J., and D.K. Lumm, 1989a, Geologic Map of the Eddyville Quadrangle, Southern Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 6, scale, 1:24,000.
- Nelson, W.J., and D.K. Lumm, 1989b, Geologic Map of the Stone-

- fort Quadrangle, Southern Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 5, scale 1:24,000.
- Nelson, W.J., J.A. Devera, R.J. Jacobson, D.K. Lumm, R.A. Peppers, C.B. Trask, C.P. Weibel, L.R. Follmer, M.H. Riggs, S.P. Esling, E.D. Henderson, and M.S. Lannon, 1991, Geology of the Eddyville, Stonefort, and Creal Springs Quadrangles: Illinois State Geological Survey, Bulletin 96, 85 p.
- North, W.G., 1969, Middle Devonian Strata of Southern Illinois: Illinois State Geological Survey, Circular 441, 45 p.
- North American Stratigraphic Code, 1983, The North American Commission on Stratigraphic Nomenclature: American Association of Petroleum Geologists Bulletin, v. 67, no. 5, p. 841–875.
- Olive, W.W., 1966a, Geologic Map of the Heath Quadrangle, McCracken and Ballard Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-561, scale 1:24,000.
- Olive, W.W., 1966b, Geologic Map of the Paducah East Quadrangle, McCracken and Livingston Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-531, scale 1:24,000.
- Olive, W.W., 1969, Geologic Map of the Bandana and Olmsted Quadrangles, McCracken and Ballard Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-799, scale 1:24,000.
- Olive, W.W., 1971, Geologic Map of Parts of the Cairo and Barlow Quadrangles, Ballard County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-885, scale 1:24,000.
- Olive, W.W., 1980, Geologic Maps of the Jackson Purchase Region, Kentucky: U.S. Geological Survey Miscellaneous Investigations Series Map I-1217, with 11-page report, scale 1:250,000.
- Palmer, J.E., 1976, Geologic Map of the Grove Center Quadrangle, Kentucky-Illinois, and Part of the Shawneetown Quadrangle, Kentucky: U.S. Geological Survey, Geologic Quadrangle Map GQ-1314, scale 1:24,000.
- Pickard, F.R., 1963, Bedrock geology of the Gorham area: M.S. thesis, Southern Illinois University, Carbondale, 70 p.
- Poor, R.S., 1925, The character and significance of the basal conglomerate of the Pennsylvanian System in southern Illinois: Transactions of the Illinois State Academy of Science, v. 18, p. 369–375.
- Pryor, W.A., and C.A. Ross, 1962, Geology of the Illinois Parts of the Cairo, La Center, and Thebes Quadrangles: Illinois State Geological Survey, Circular 332, 39 p.
- Rhoades, R.F., and A.J. Mistler, 1941, Post-Appalachian faulting in western Kentucky: American Association of Petroleum Geologists Bulletin, v. 25, no. 11, p. 2046–2056.
- Rogers, J.E., 1972, Silurian and Lower Devonian stratigraphy and paleobasin development—Illinois Basin, central United States: Ph.D. thesis, University of Illinois at Urbana-Champaign, 144 p.
- Rogers, W.B., 1963, Geology of the Eddyville Quadrangle, Lyon and Caldwell Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-255, scale 1:24,000.
- Rogers, W.B., and W.H. Hays, 1967, Geologic Map of the Fredonia Quadrangle, Caldwell, Crittenden, and Lyon Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-607, 1:24,000.
- Ross, C.A., 1963, Structural Framework of Southernmost Illinois: Illinois State Geological Survey, Circular 351, 27 p.
- Ross, C.A., 1964, Geology of the Paducah and Smithland Quadrangles in Illinois: Illinois State Geological Survey, Circular 360, 32 p.
- Sable, E.G., and G.R. Dever, Jr., 1990, Mississippian Rocks in Kentucky: U.S. Geological Survey, Professional Paper 1503, 125 p.
- Safford, J.M., 1869, Geology of Tennessee: S.C. Mercer, Nashville, TN, 550 p.
- Satterfield, I.R., 1971, Conodonts and stratigraphy of the Girardeau Limestone (Ordovician) of southeastern Missouri and southwestern Illinois: Journal of Paleontology, v. 45, no. 2, p. 265–273.
- Satterfield, I.R., 1973, Bedrock Geologic Map of the Cape Girardeau and McClure Quadrangles, Southeastern Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-82-73-GI, scale 1:24,000.
- Savage, T.E., 1920, Devonian formations of Illinois: American Journal of Science, v. 49, p. 169–182.
- Schwalb, H.R., 1982, Paleozoic Geology of the New Madrid Area: U.S. Nuclear Regulatory Commission, NUREG/CR-2909, 61 p.
- Schwalb, H.R., and P.E. Potter, 1978, Structure and Isopach Map of the New Albany-Chattanooga-Ohio Shale (Devonian and Mississippian) in Kentucky—Western Sheet: Kentucky Geological Survey, Series X, 1978.
- Seeland, D.A., 1968, Geologic Map of the Repton Quadrangle, Crittenden County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-754, scale 1:24,000.
- Shaver, R.H., 1974, The Muscatatuck Group (new Middle Devonian name) in Indiana: Indiana Geological Survey Occasional Paper 3, 7 p.
- Shaver, R.H., coordinator, 1984, Midwestern basins and arches correlation chart: American Association of Petroleum Geologists, Correlation of Stratigraphic Units in North America (COSUNA) Chart Series MBA.
- Shaver, R.H., and 16 others, 1986, Compendium of Paleozoic Rock-Unit Stratigraphy in Indiana—A Revision: Indiana Geological Survey, Bulletin 59, 203 p.
- Shaw, E.W., and T.E. Savage, 1912, Description of the Murphysboro-Herrin Quadrangles: U.S. Geological Survey Geologic Atlas Folio 185, 15 p.
- Siever, Raymond, 1951, The Mississippian-Pennsylvanian unconformity in southern Illinois: American Association of Petroleum Geologists Bulletin, v. 35, no. 3, p. 542–581.
- Smith, A.E., and J.E. Palmer, 1974, More testing needed in thrust faults of western Kentucky's Rough Creek fault system: The Oil and Gas Journal, July 8, 1974, p. 133–138.
- Smith, W.H., 1957, Strippable Coal Reserves of Illinois, Part 1, Gallatin, Hardin, Johnson, Pope, Saline, and Williamson Counties: Illinois State Geological Survey, Circular 228, 39 p.
- Smith, W.H., 1958, Strippable Coal Reserves of Illinois, Part 1, Jackson, Monroe, Perry, Randolph, and St. Clair Counties: Illinois

- State Geological Survey, Circular 260, 35 p.
- Sonnefield, R.D., 1981, Geology of northwestern Jackson County, with special emphasis on the Caseyville Formation: M.S. thesis, Southern Illinois University, Carbondale, 84 p.
- Sullivan, D.M., 1972, Subsurface Stratigraphy of the West Baden Group in Indiana: Indiana Geological Survey, Bulletin 47, 31 p.
- Swann, D.H., 1963, Classification of Genevievian and Chesterian (late Mississippian) Rocks of Illinois: Illinois State Geological Survey, Report of Investigations 216, 91 p.
- Swann, D.H., J.A. Lineback, and Eugene Frund, 1965, The Borden Siltstone (Mississippian) Delta in Southwestern Illinois: Illinois Geological Survey, Circular 386, 20 p.
- Swann, D.H., and H.B. Willman, 1961, Megagroups in Illinois: American Association of Petroleum Geologists Bulletin, v. 45, p. 471–483.
- Swanson, R.W., 1978, Geologic Map of the La Center Quadrangle, Ballard and McCracken Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-141, scale 1:24,000.
- Taylor, R.F., 1967, Areal geology of the Brownfield Quadrangle, southeastern Illinois: M.S. thesis, Southern Illinois University, Carbondale, 103 p.
- Templeton, J.S., and H.B. Willman, 1963, Champlainian Series (Middle Ordovician) in Illinois: Illinois State Geological Survey, Bulletin 89, 260 p.
- Thompson, T.L., 1991, Paleozoic Succession in Missouri, Part 2, Ordovician System: Missouri Division of Geology and Land Survey, Report of Investigations 70, 282 p.
- Thompson, T.L., 1986, Paleozoic Succession in Missouri, Part 4, Mississippian System: Missouri Division of Geology and Land Survey, Report of Investigations 70, 182 p.
- Thompson, T.L., and I.R. Satterfield, 1975, Stratigraphy and Conodont Biostratigraphy of Strata Contiguous to the Ordovician-Silurian Boundary in Eastern Missouri: Missouri Geological Survey, Report of Investigations 57, p. 61–108.
- Tikrity, S.S., 1968, Tectonic genesis of the Ozark uplift: Ph.D. dissertation, Washington University, St. Louis, Missouri.
- Trace, R.D., 1962, Geology of the Salem Quadrangle, Crittenden and Livingston Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-206, scale 1:24,000.
- Trace, R.D., 1966, Geologic map of the Marion Quadrangle, Crittenden and Caldwell Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-547, scale 1:24,000.
- Trace, R.D., 1974a, Illinois-Kentucky fluorspar district, in D. W. Hutcherson, editor, A Symposium on the Geology of Fluorspar: Kentucky Geological Survey, Series X, Special Publication 22, p. 58–76.
- Trace, R.D., 1974b, Geologic Map of the Cave in Rock Quadrangle, Crittenden County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1201, scale 1:24,000.
- Trace, R.D., 1976, Geologic Map of the Lola Quadrangle, Crittenden and Livingston Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1288, scale 1:24,000.
- Trace, R.D., and D.H. Amos, 1984, Stratigraphy and Structure of the Western Kentucky Fluorspar District: U.S. Geological Survey Professional Paper 1151-D, 41 p.
- Trask, C.B., and R.J. Jacobson, 1990, Geologic Map of the Creal Springs Quadrangle, Johnson and Williamson Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 4, scale 1:24,000.
- Treworgy, J.D., 1981, Structural Features in Illinois—A Compendium: Illinois State Geological Survey, Circular 519, 22 p., map scale about 1:70,000.
- Treworgy, J.D., 1988, The Illinois Basin—A Tectonically and Tectonically Influenced Ramp During Mid-Chesterian Time: Illinois State Geological Survey, Circular 544, 20 p.
- Treworgy, J.D., 1991, Kaskaskia Sequence—Mississippian, Valmeyeran, and Chesterian Series, in M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, editors, Interior Cratonic Basins: American Association of Petroleum Geologists Memoir 5, p. 125–142.
- Ulrich, E.O., 1905, Geology and general relations, in E.O. Ulrich and W.S. Tangier-Smith, The Lead, Zinc, and Fluorspar Deposits of Western Kentucky: U.S. Geological Survey Professional Paper 36, p. 7–105.
- Viele, G.W., 1983, Collision effects on the craton caused by the Ouachita orogeny: Geological Society of America, Abstracts with Programs, v. 15, p. 712.
- Vincent, J.W., 1975, Lithofacies and Biofacies of the Haney Limestone (Mississippian), Illinois, Indiana and Kentucky: Kentucky Geological Survey, Series X, Thesis Series 4, 64 p.
- Weibel, C.P., and W.J. Nelson, 1993, Geologic Map of the Lick Creek Quadrangle, Johnson, Union, and Williamson Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 12, scale 1:24,000.
- Weibel, C.P., W.J. Nelson, and J.A. Devera, 1991, Geologic Map of the Waltersburg Quadrangle, Pope County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle 8, scale 1:24,000.
- Weller, J.M., 1944, Devonian System in Southern Illinois: Illinois State Geological Survey, Bulletin 68, p. 89–102.
- Weller, J.M., and G.E. Ekblaw, 1940, Preliminary Geologic Map of Parts of the Alto Pass, Jonesboro, and Thebes Quadrangles in Union, Alexander, and Jackson Counties: Illinois State Geological Survey, Report of Investigations 70, 26 p.
- Weller, J.M., R.M. Grogan, and F.E. Tippie, 1952, Geology of the Fluorspar Deposits of Illinois: Illinois State Geological Survey, Bulletin 76, 147 p.
- Weller, J.M., and A.H. Sutton, 1940, Mississippian border of Eastern Interior basin: American Association of Petroleum Geologists Bulletin, v. 24, no. 5, p. 765–858.
- Weller, Stuart, 1913, Stratigraphy of the Chester Group in southwestern Illinois: Transactions of the Illinois State Academy of Science, v. 6, p. 118–129.
- Weller, Stuart, 1920, The Chester Series in Illinois: Journal of Geology, v. 28, nos. 4, 5, p. 281–303, 395–416.

- Weller, Stuart, and F.F. Krey, with contribution by J.M. Weller, 1939, Preliminary Geologic Map of the Mississippian Formations in the Dongola, Vienna, and Brownfield Quadrangles: Illinois State Geological Survey, Report of Investigations 60, 11 p.
- Weller, Stuart, and Stuart St. Clair, 1928, Geology of Ste. Genevieve County, Missouri: Missouri Bureau of Geology and Mines, 2nd series, Vol. XXII, 352 p.
- Weller, Stuart, and J.M. Weller, 1939, Preliminary Geological Maps of the pre-Pennsylvanian Formations in Part of Southwestern Illinois—Waterloo, Kimmswick, New Athens, Crystal City, Renault, Baldwin, Chester, and Campbell Hill Quadrangles: Illinois State Geological Survey, Report of Investigations 59, 15 p.
- Whitaker, S.T., 1988, Silurian Pinnacle Reef Distribution in Illinois: Model for Hydrocarbon Exploration: Illinois State Geological Survey, Illinois Petroleum 130, 32 p.
- Whitfield, J.W., and M.A. Midden-dorf, 1989, Bedrock Geologic Map of the Neelys Landing 7.5-Minute Quadrangle, Cape Girardeau County, Missouri: Missouri Division of Geology and Land Survey, Open File Map OFM-89-254-GI, scale 1:24,000.
- Willman, H.B., et al., 1967, Geologic Map of Illinois: Illinois State Geological Survey, scale 1:500,000.
- Willman, H.B., Elwood Atherton, T.C. Buschbach, Charles Collin-son, J.C. Frye, M.E. Hopkins, J.A. Lineback, and J.A. Simon, 1975, Handbook of Illinois Stratigraphy: Illinois State Geological Survey, Bulletin 95, 261 p.
- Wilson, M.E., 1922, The Occurrence of Oil and Gas in Missouri: Missouri Bureau of Geology and Mines, 2nd Series, v. 16, 284 p.
- Workman, L.E., and Tracey Gillette, 1956, Subsurface Stratigraphy of the Kinderhook Series in Illinois: Illinois State Geological Survey, Report of Investigations 189, 46 p.
- Worthen, A.H., 1866, Geology: Geological Survey of Illinois, v. 1, 504 p.
- Zartman, R.E., M.R. Brock, A.V. Heyl, and H.H. Thomas, 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from central and eastern United States: American Journal of Science, v. 265, no. 10, p. 848–870.

ADDENDUM TO PLATES 1 TO 5

The revisions made to the stratigraphic nomenclature since the completion of the Paducah map and stratigraphic columns are as follows:

For Maquoketa Group (Ordovician) read Maquoketa Formation.

For Cape La Croix Shale Formation (oldest) read Cape La Croix Shale Member.

For Thebes Sandstone Formation read Thebes Sandstone Member.

For Orchard Creek Shale Formation read Orchard Creek Shale Member.

For Girardeau Limestone Formation read Girardeau Limestone Member.

For Bainbridge Group (Silurian) read Bainbridge Formation.

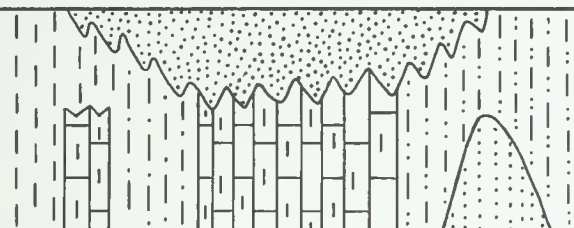
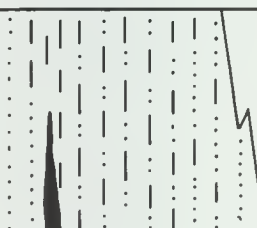
For St. Clair Limestone Formation read St. Clair Limestone Member.

For Moccasin Springs Formation read Moccasin Springs Member.

For Tamms group (Silurian and Devonian) read Tamms group of Rogers (1972). (This unit does not yet have a formal name in Illinois.)

For St. Laurent, Lingle, and Alto Formations read St. Laurent Formation. (Use of the names Lingle and Alto Formations is discontinued in Illinois; use of the name St. Laurent Formation is extended from Missouri into Illinois.)

For Drury Member of the Caseyville Formation (Pennsylvanian) read unnamed member. (The name Drury Member no longer refers to a unit in the Caseyville Formation because new mapping shows that the unit originally called "Drury" is actually part of the Tradewater Formation.)

System	Series	Group or Formation	Member or Bed	Graphic Column	Thickness in Feet
Permian	Wolfcampian				Union County, Ky.
	Virgilian		Geiger Lake Coal Bed		
	?				

Desmoinesian	
McLeansboro Group	No. 14 Coal Bed (Ky.)
Piasa Ls. Mbr. (west)	
Danville Coal Mbr.	
Allenby Coal Mbr.	
Bankston Fork Ls. Mbr.	
Anvil Rock Ss. Mbr.	
Brereton Provi- dence Ls. Mbr.	
Herrin Coal Mbr.	
Briar Hill Coal Mbr.	
Springfield Coal Mbr.	
Houchin Creek Coal Mbr.	
Carbondale Formation	
Survant Coal Mbr.	
Colchester Coal Mbr.	
Dekoven Coal Mbr.	
	275- 400
	450- 525
	2600 ± in graben, Union County, Ky.

D
North

Franklin Co. | Williamson Co.
②

Williamson Co. | Saline Co.

Cottage Grove
Fault System

④

Feet

5000

10,000

15,000

2x vertical exaggeration

Precambrian crystalline rocks

OC

P

Mp

Mv

MDna

Dml

Som

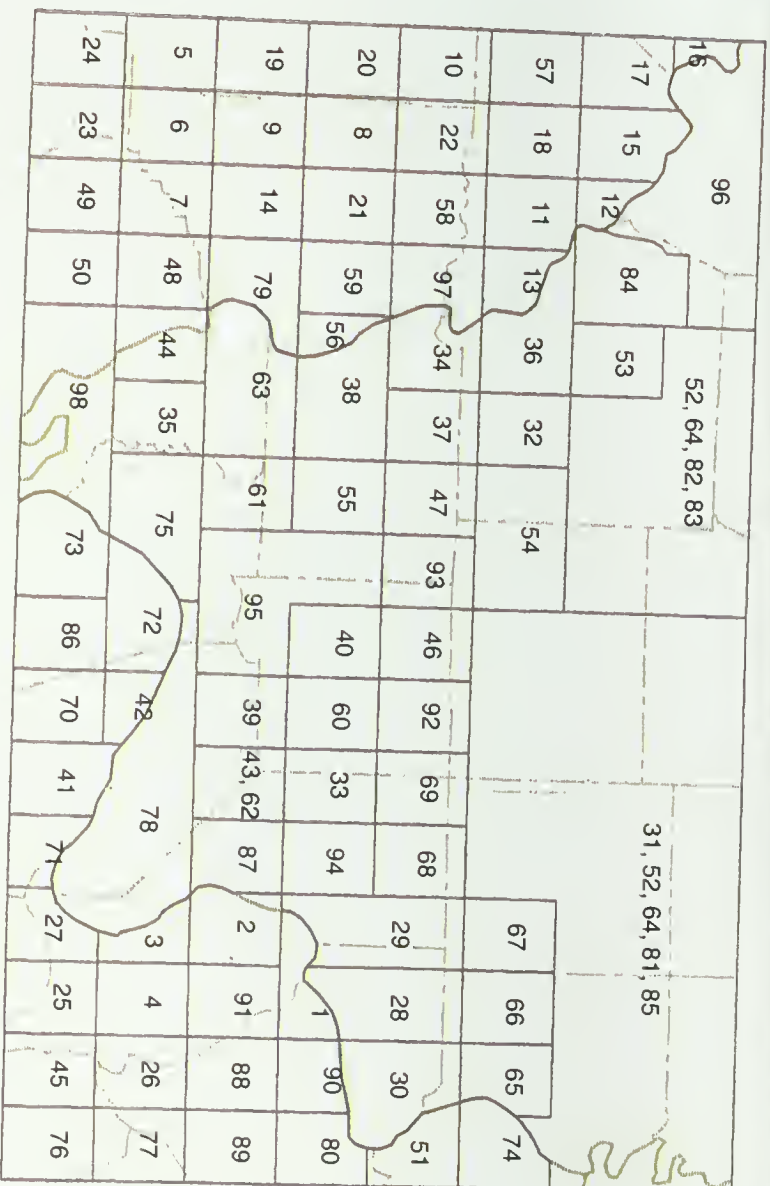
A
T

A
T

?

?





1. Amos, Dewey, H., 1965, Geology of the Shelterville and Rosiclare Quadrangles, Livingston and Crittenden Counties, Kentucky: U.S. Geological Survey Map GQ-400, scale 1:24,000.
2. Amos, Dewey, H., 1966, Geologic map of the Golconda and Brownfield Quadrangles, Livingston County, Kentucky, U.S. Geological Survey Map GQ-546, scale 1:24,000.
3. Amos, Dewey, H., 1967, Geologic map of the Smithland Quadrangle, Livingston County, Kentucky: U.S. Geological Survey Map GQ-557, scale 1:24,000.
4. Amos, Dewey, H., 1974, Geologic map of the Burna Quadrangle, Livingston County, Kentucky: U.S. Geological Survey Map GQ-1150, scale 1:24,000.
5. Amos, Dewey, H., 1981a, Geologic map of the Dongola Quadrangle, Bollinger and Stoddard Counties, Missouri: U.S. Geological Survey Map MF-1363, scale 1:24,000.
6. Amos, Dewey, H., 1981b, Geologic map of the Whitewater Quadrangle, Bollinger and Cape Girardeau Counties, Missouri: U.S. Geological Survey Map MF-1256, scale 1:24,000.
7. Amos, Dewey, H., 1981c, Geologic map of the Chatfee Quadrangle, Scott and Cape Girardeau Counties, Missouri: U.S. Geological Survey Map MF-1316, scale 1:24,000.
8. Amos, Dewey, H., 1982a, Geologic map of the Millersville Quadrangle, Cape Girardeau and Bollinger Counties, Missouri: U.S. Geological Survey Map MF-1459, scale 1:24,000.
9. Amos, Dewey, H., 1982b, Geologic map of the Burfordville Quadrangle, Cape Girardeau and Bollinger Counties, Missouri: U.S. Geological Survey map MF-1385, scale 1:24,000.
10. Amos, Dewey, H., 1984, Geologic map of the Sedgewickville Quadrangle, Bollinger and Perry Counties, Missouri: U.S. Geological Survey Map MF-1674, scale 1:24,000.
11. Amos, Dewey, H., 1985d, Geologic map of the Gordonville Quadrangle, Cape Girardeau County, Missouri: U.S. Geological Survey Map 1823, scale 1:24,000.
12. Amos, Dewey, H., 1986a, Geologic map of the Belgique 7.5-m Quadrangle, Perry County, Missouri: Missouri Geological Survey OFM-86-234-GI, scale 1:24,000.
13. Amos, Dewey, H., 1986b, Geologic map of the Kaskaskia 7.5-m Quadrangle, Site, Genevieve County, Missouri: Missouri Geological Survey OFM-85-232-GI, scale 1:24,000.
14. Amos, Dewey, H., 1986c, Geologic map of the Lithium 7.5-min Quadrangle, Perry and Site, Genevieve Counties, Missouri: Missouri Geological Survey OFM-86-233-GI, scale 1:24,000.
15. Amos, Dewey, H., 1986d, Geologic map of the Perryville East 1-minute Quadrangle, Perry County, Missouri: Missouri Geological Survey open file map, scale 1:24,000.
16. Amos, Dewey, H., 1987a, Geologic map of the Marble Hill Quadrangle, Bollinger County, Missouri: U.S. Geological Survey Map MF-1317, scale 1:24,000.
17. Amos, Dewey, H., 1987b, Geologic map of the Scopus Quadrangle, Bollinger County, Missouri: U.S. Geological Survey Map MF-1905, scale 1:24,000.
18. Amos, Dewey, H., 1987c, Geologic map of the Jackson Quadrangle, Cape Girardeau County, Missouri: U.S. Geological Survey Map MF-1906, scale 1:24,000.
19. Amos, Dewey, H., 1987d, Geologic map of the Friedheim Quadrangle, Cape Girardeau, Bollinger, and Perry Counties, Missouri: U.S. Geological Survey Map MF-1905, scale 1:24,000.
20. Amos, Dewey, H., and D.D. Blankenship, 1980a, Geologic map of the Bell City Quadrangle, Stoddard and Scott Counties, Missouri: U.S. Geological Survey Map MF-1206, scale 1:24,000.
21. Amos, Dewey, H., and D.D. Blankenship, 1980b, Geologic map of the Advance Quadrangle, Stoddard and Bollinger Counties, Missouri: U.S. Geological Survey Map MF-1197, scale 1:24,000.
22. Amos, Dewey, H., and W.I. Finch, 1968, Geologic map of the City Quadrangle, Livingston and Marshall Counties, Kentucky: U.S. Geological Survey Map GQ-731, scale 1:24,000.
23. Amos, Dewey, H., and W.H. Hays, 1974, Geologic map of the Licking Quadrangle, Crittenden, Livingston, and Lyon Counties, Kentucky: U.S. Geological Survey Map GQ-1149, scale 1:24,000.

System		Group or Formation	Member or Bed	Graphic Column	Thickness in Feet					
Series										
Missourian		McLeansboro Group	Carthage Ls. M. New Haven Coal Mbr.		1-10 0-1					
			Macoupin Ls. M. Womac C. M.		1-3 0-3					
			Cramer Ls. M. Chapel C. M.		0-2 0-2 1/2					
					550 (max.)					
			Lake Creek C. M.		0-2					
			Pond Creek C. M.		0-2					
			DeGraff Coal M. Piassa Ls. Mbr.		0-2 0-8					

-10,000 -

Precambrian crystalline rock

2x vertical exaggeration

A Southwest

Bollinger Co.

Cape Girardeau Co.

Perry Co.

Och

0

Och

Ocn

C

Feet

-5000 -

-10,000 -

2x vertical exaggeration

Precambrian crystal

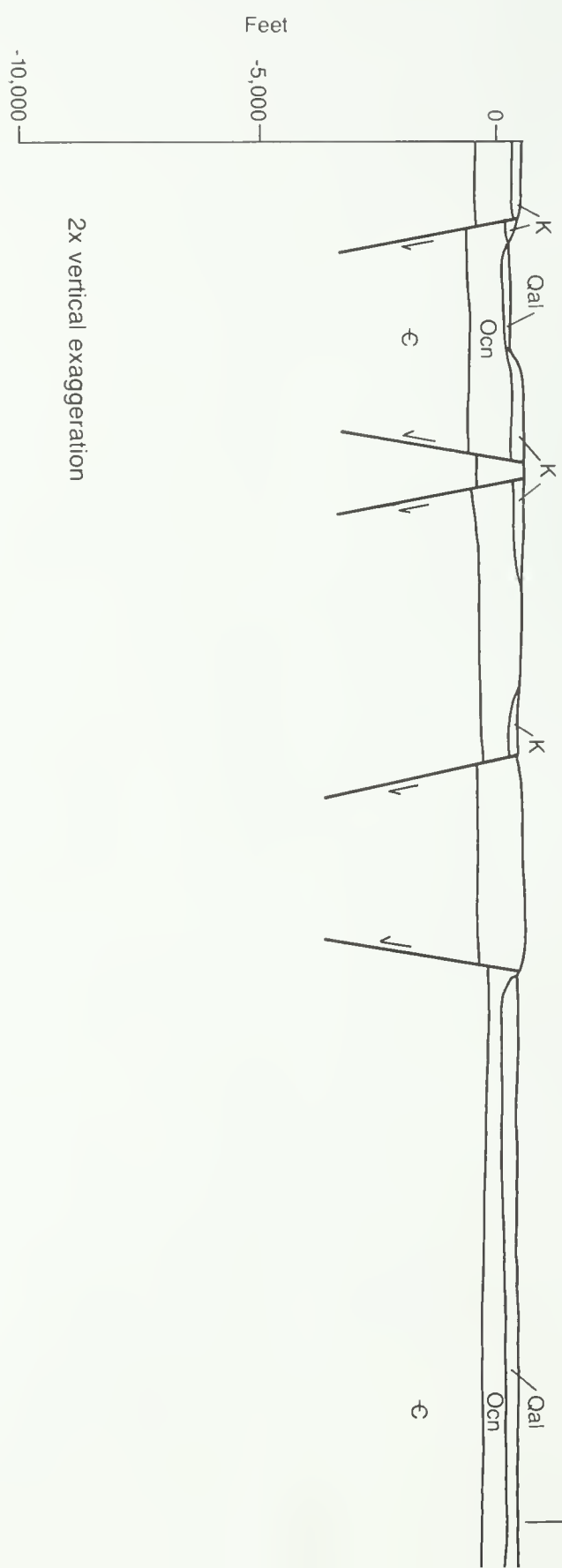
Cretaceous			Tertiary			System	
Upper (Gulfian)			Paleocene		Eocene	Series	
Tuscaloosa Gravel	McNairy Formation	Levings Mbr.	Owl Creek Fm.	Midway Gp.	Wilcox Sand	Clalborne Formation	
			Clayton Fm.	Porters Creek Clay			

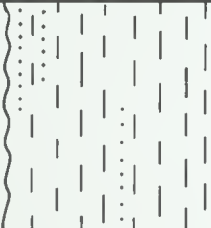
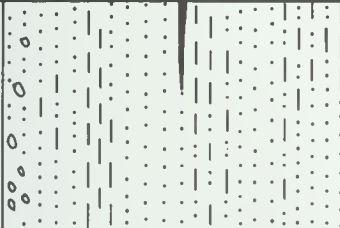
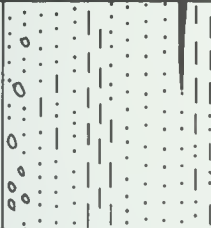
Chest.		lower Pope Gp.		St. Genevieve Limestone	Fredonia Limestone Mbr.	St. Louis Limestone	
1		Aux Vases Sandstone	Karnak Ls. Mbr. Spar Mt. Ss.				
							
							
							
							

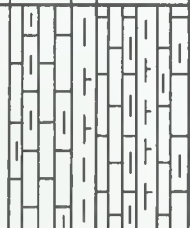
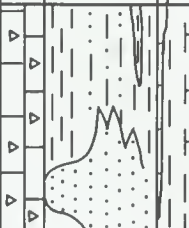
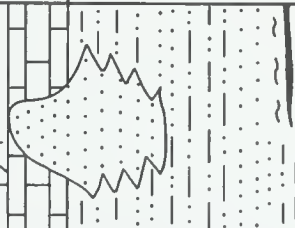
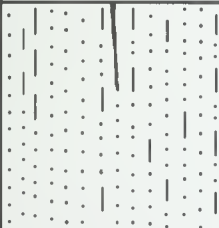
2x vertical exaggeration

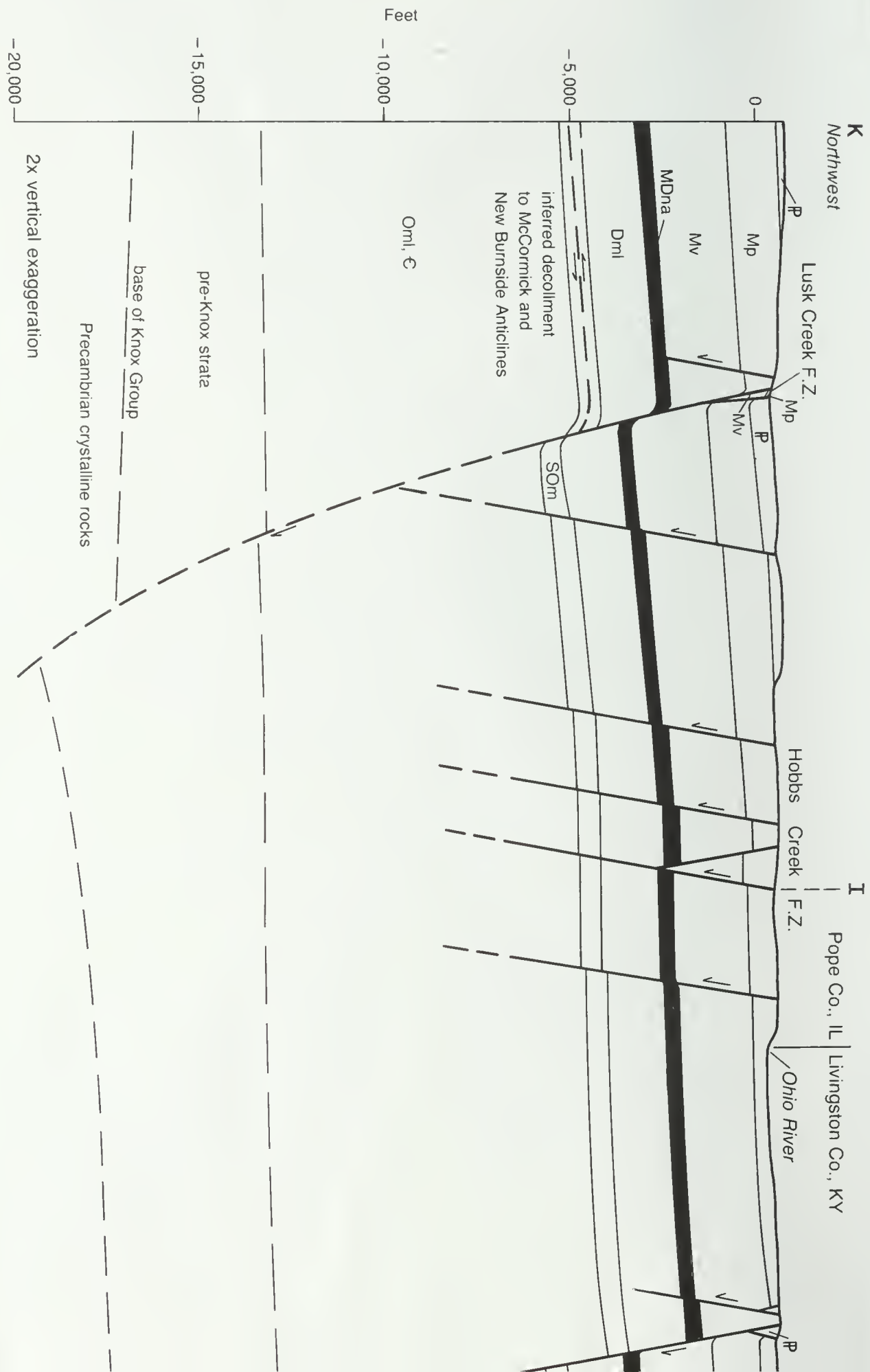
-10,000

F
Southwest



System	Series	Group or Formation	Member or Bed	Graphic Column	Thickness in Feet
Tertiary	Eocene	Clairborne Formation			0-180
		Wilcox Sand			0-200
	Paleocene	Porters Creek Clay			0-220
		Clayton Formation -----? -----			0-300
Cretaceous	Upper	McNairy Formation			0-180
		Tuscaloosa Gravel			

Chesterian					
Palestine Sandstone			45-75		
Menard Limestone	Allard Limestone		80- 150		
Waltersburg Sandstone			25-85		
Vienna Ls.			10-40		
Tar Springs Sandstone			70- 145		
Glen Dean Limestone			40-90		
Hardinsburg Sandstone			40- 150		
Golconda Formation	Haney Limestone		40-90		
	Fraileys Shale Mbr.		40-90		
			90- 180		



UNIVERSITY OF ILLINOIS-URBANA



3 0112 121906991